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The Separate and Collective Effects of Personalization, Personification, and Gender on Learning with Multimedia Chemistry Instructional Materials

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The University of San Francisco

THE SEPARATE AND COLLECTIVE EFFECTS OF
PERSONALIZATION, PERSONIFICATION, AND GENDER
ON LEARNING WITH
MULTIMEDIA CHEMISTRY INSTRUCTIONAL MATERIALS

A Dissertation Presented
to
The Faculty of the School of Education
Learning and Instruction Department

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

by
Shannon Halkyard
San Francisco
May 2012

THE UNIVERSITY OF SAN FRANCISCO
Dissertation Abstract

The Separate and Collective Effects of Personalization, Personification, and Gender on Learning with Multimedia Chemistry Instructional Materials

Chemistry is a difficult subject to learn and teach for students in general. Additionally, female students are under-represented in chemistry and the physical sciences. Within chemistry, atomic and electronic structure is a key concept and several recommendations in the literature describe how this topic can be taught better.

These recommendations can be employed in multimedia instructional materials designed following principles understood through the Cognitive Theory of Multimedia Learning. Additionally, these materials can expand the known use of principles like personalization (addressing the learner as “you”) and test prospective design principles like personification (referring to abstract objects like atoms as “she” or “he”).

The purpose of this study was to use the recommendations on teaching atomic and electronic structure along with known multimedia design principles to create multimedia chemistry learning materials that can be used to test the use of personalization and personification both separately and together. The study also investigated how learning with these materials might be different for male and female students.

A sample of 329 students from private northern California high schools were given an atomic structure pre-test, watched a multimedia chemistry

instructional video, and took a post-test on atomic structure. Students were randomly assigned to watch one of six versions of the instructional video.

Students in the six groups were compared using ANOVA procedures and no significant differences were found. Males were compared to females for the six different treatment conditions and the most significant difference was for the treatment that combined personalization (you) and female personification (she), with a medium effect size (Cohen's $d=0.65$). Males and females were then compared separately across the six groups using ANOVA procedures and t-tests. A significant difference was found for female students using the treatment that combined personalization (you) and female personification (she) compared to the group with no personalization or personification, with a medium-large effect size (Cohen's $d=0.75$).

Further research is needed to eliminate possible confounding and other factors, but the study results indicate that personalization and personification likely have positive effects on learning, especially for female students.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

Shannon J. Halkyard May 11, 2012
Candidate

Dissertation Committee

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Dr. Xornam Apedoe May 11, 2012

Dr. Susan Prion May 11, 2012

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Dedication

To my mother Janice

and

To the students and teachers who continue to help to improve teaching and learning

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Chapter 1

Introduction

Statement of the Problem

Forty percent of students who plan to major in science and engineering in college change majors (Drew, 2011). That percentage increases to 60 percent when pre-medical students are included and is four times as high as the attrition rates for other majors (Drew, 2011). The need for more science and engineering majors has led President Obama, in conjunction with industry groups, to call for colleges and universities to graduate 10,000 more engineers per year and 100,000 new teachers with majors in science, technology, engineering and mathematics (Drew, 2011).

Chemistry is regarded as a difficult subject. It explains the world using abstract concepts and highly specialized jargon and symbol sets that students struggle to learn and understand (Colburn, 2009). An example of the abstract concepts in chemistry is the model of the atom and the arrangement of electrons within atoms. Models of the atom and electronic structure are difficult and complex because there are many parts of the atom that must be considered and kept in mind all at the same time (Millikan, 1982; MacKinnon, 1999, Chandler & Sweller, 1991). Students and even teachers are known to have trouble with this content area and there have been many recommendations for improving the teaching of this content (Millikan, 1982; MacKinnon, 1999; Strong, 1986; Rich & Sutter, 1988; Gillespie et al., 1996).

In addition to being a difficult subject, chemistry is one of the fields of study where gender segregation has been relatively stagnant for the past 20 years (Alon & Gelbsinger, 2011). Gender segregation had been decreasing in the 1970s and 1980s,

but that pattern has been replaced by stagnation beginning in the 1990s (Alon & Gelbsinger, 2011; Charles & Bradley, 2002). More women than men complete college (Buchmann & DiPrete, 2006) and receive more bachelors, masters, and doctoral degrees than men do (Snyder & Dillow, 2010), but integration of women into science, technology, engineering, and math (STEM) has been slow for most STEM majors (Turner & Bowen, 1999; Xie & Shauman, 2003). The low number of women receiving degrees in STEM is an important social policy issue given concerns about a nationwide shortage of STEM graduates (Mann & DiPrete, 2011).

In 1977, 37 percent of all STEM bachelors degrees were awarded to women, but women exceeded men in the number of bachelors degrees received beginning in 2000 (Mann & DiPrete, 2011). This statistic conceals two other trends, however. Even though more women are receiving science degrees, there is a disproportionate female preference for non-science majors (Mann & DiPrete, 2011). In addition to this preference, there is a second preference among women for life science degrees (Mann & DiPrete, 2011). The combination of these two preferences has resulted in a change in the percentage of women receiving life science degrees from 50 to 70 percent since 1980 (Mann & DiPrete, 2011). Any female advantage in science degrees is limited to life science degrees, and gender segregation remains a problem in all other STEM fields (Mann & DiPrete, 2011).

One possible tool to address the needs to improve student learning of chemistry and to increase women's involvement in science is to use multimedia instructional materials that can improve learning and increase female involvement. Multimedia instructional materials and the Cognitive Theory of Multimedia Learning

(CTML) provide a way to learn and manage complex material like chemistry (Mayer, 2001). Multimedia instructional materials allow for delivery of academic content through visual and auditory senses and CTML explains how these materials are processed mentally (Mayer, 2001). Humans possess separate visual and auditory processing channels that can be used together to perform learning tasks (Mayer, 2001).

The processing involved in learning through the two channels includes extraneous processing of unnecessary material that may be present, essential processing that is required to mentally represent and understand the material, and generative processing that is required to integrate the new learning with prior knowledge (Mayer, 2001). While many design principles show how to reduce and eliminate extraneous processing and how to manage essential processing, some design principles show how to increase generative processing to improve learning (Mayer, 2001).

Social agency principles are one group of design principles that promote generative processing and increase learning outcomes by using social cues to elicit a social response (Moreno & Mayer, 2010). One example of such a principle is the personalization effect, where the learner is addressed directly using informal language and pronouns (Moreno & Mayer, 2010). Changing the language of instruction from “the diaphragm moves down creating more space for the lungs” to “*your* diaphragm moves down creating more space for *your* lungs” is an example of applying the personalization effect (Mayer et al., 2004).

Personification provides another way to use social cues to promote learning. Personification is when an inanimate object is described using the language associated with people, such as he and she, to indicate that it is a social agent and to generate a social response and an increase in learning. An example of this would be the change from “the diaphragm moves down creating more space for the lungs” to “the diaphragm moves down and *he* creates more space for the lungs.” Furthermore, personification (s/he) and personalization (you) could be used together and there is the potential for a synergistic effect. An example of personification (s/he) and personalization (you) being used together could be “*your* diaphragm moves down and *he* creates more space for your lungs.”

Personification can use feminine or masculine pronouns (she creates or he creates in the preceding examples) and there the possibility that using she or he can have different effects for male and female students. Female students may respond better to female personification (she) and male students may respond better to male personification (he), but the details and existence of this possible interaction are not currently known. Because of the possible interaction, it is important to measure whether learning outcomes are different for males and females using personified (s/he) materials with feminine and masculine pronouns.

Significance of the Problem

The problem in this study is significant at multiple levels. First, there is a practical need for additional instructional methods to help students learn difficult subjects such as chemistry (Drew, 2011). Other multimedia studies have shown ways to improve instruction with these tools in science and this study aims to extend the

known range for one of these tools (personalization, you) to include chemistry and to possibly add a new tool (personification, s/he) for improving science instruction.

This study will also address whether combining the tools of personalization (you) and personification (s/he) leads to even greater learning for students using instructional chemistry videos.

Second, while there has been progress in addressing gender inequalities in some areas of science, chemistry is one of the areas where gender inequalities persist (Nosek, 2009; NSF, 2012) and this study may indicate ways to improve interest and participation in chemistry and other sciences for female students. More specifically, this study can indicate ways to not only counter stereotype threat to improve the performance of females in science, but it can possibly identify ways to modify instructional materials to more effectively teach science for females.

Background and Need

Chemistry As a Difficult Knowledge Domain.

Instructional tools like personalization (you) and personification (s/he) are useful as chemistry is known to be a difficult knowledge domain. Chemistry explains the world using abstract concepts and a unique language and symbol set that students struggle to organize, understand, and integrate into their existing knowledge for meaningful learning (Colburn, 2009). *Chemistry is difficult* is a paradigm that may be a result from the many different concepts and algorithms that students must learn and coordinate to succeed in studying the subject (Breuer, 2002). Chemistry's reputation as difficult to learn and the demands students must meet in order to learn the subject

may be leading to the decrease in post-secondary enrollment in chemistry courses noted in the literature over the past thirty years (Tai et al., 2006).

Electronic structure misconceptions and teaching recommendations.

Within chemistry, the area of atomic electronic structure includes the specifics of electron configurations, quantum numbers, shells, subshells, orbitals, and more. Documentation of the difficulties of learning and peculiarities of teaching electronic structure dates back to 1982 (Millikan, 1982). In addition to Millikan's opinion, MacKinnon reports many misconceptions among students concerning electron configurations (1999). MacKinnon gave instructors a survey and told them to distribute it "randomly" to their students. The survey was given as a pilot study with 20 college students and then with 302 twelfth grade students. The identified student misconceptions were:

- confusion over terminology, which was cited repeatedly,
- rote use of a memory-aid (described as a "snake-like ordering chart"),
- the misconception that a pattern constituted a reason for a model,
- the visualization of orbitals as being only two-dimensional, and
- confusion and incomplete understanding of principles, like the Aufbau principle.

There have been several recommendations on teaching electron configurations and models of the atom. MacKinnon (1999) recommends that teachers help students to recognize patterns in the periodic table and to use those patterns to establish and justify models. MacKinnon also describes research indicating that there is a "very clear link between a weak descriptive language base and the logical development of

science concepts.” He also comments that instruction should be heads-on rather than just hands-on.

Also to improve teaching of electron configurations, Strong (1986) presents the use of the periodic table as a learning tool and tracking device for teaching and determining electron configurations. She designates the s, p, d, and f blocks, then refers to the label as designating the most recently added electron. The columns of each block are numbered to represent the number of electrons within each subshell or block. As well, the row numbers are used to identify the s and p subshells. The d and f subshells are described as filling one and two rows late. Strong then provides a figure that highlights configurations that do not follow the pattern predicted by the Aufbau principle. She separates the exceptions into those that can be explained by Hund’s rule and those that require different explanations.

Rich and Sutter (1988) also make suggestions for ways to improve teaching atomic electronic structure. They present graphical data to demonstrate some common misconceptions, not only amongst students of chemistry, but also among teachers and textbooks, including misconceptions about why half full and full electron shells and subshells seem to be more energetically favorable and stable than other configurations. Rich and Sutter state that texts and teachers commonly describe half-full and full shells and subshells as being especially stable configurations for electrons when the periodic trend in ionization energy essentially reflects increased effective nuclear charge. Rich and Sutter also explain the energetic preference for half-full configurations as the avoidance of Coulombic repulsion.

In a departure from teaching electronic structure from a solely theoretical view that focuses on the atomic model, Gillespie et al. (1996) recommend and present a method for teaching the atomic model starting from experimental evidence. Gillespie et al. focus on shells and subshells of atoms as a reasoned and reasonable model for the experimental evidence on ionization energies. They also promote using the periodic table as an assistive tool in constructing the model. The need for a tool and model are a result of the complexity of the atomic model, especially the organization of electrons into orbitals nested in subshells that are in turn nested in shells. Complex models put great demands on cognitive processing and require tools like the periodic table for constructing and understanding the models.

Summary.

Chemistry is a difficult subject and within chemistry, atoms and electronic structure are one area where misconceptions abound for both students and teachers (Millikan, 1982; MacKinnon, 1999; Strong, 1986). Recommendations for improving the teaching of the atomic model and electronic structure have included focusing on the Periodic Table as a graphical aid (MacKinnon, 1999; Strong, 1986), focusing on Coulomb's Law to explain features of the model (Rich & Sutter, 1988) and building the model up from experimental ionization data (Gillespie et al., 1996). Multimedia materials present an opportunity to incorporate these recommendations and to address the many interacting elements in the atomic model and electronic structure.

Gender and Science Education.

In addition to a general need to address learning in science and chemistry, there is a need to address the under-representation of females in the fields of science,

technology, engineering, and mathematics (STEM; Nosek et al., 2009). Of the doctoral degrees awarded in the U.S. between 2001 and 2009, women accounted for 49% of all doctoral degrees, but only 35% of science degrees, 29% of physical science degrees, and 35% of chemistry degrees. (NSF, 2012). While there appears to be a trend toward improving women's representation in science, that improvement has been limited to biological sciences over the last 20 years, with continuing low representation of women in other STEM fields (Mann & DiPrete, 2011). From 2001 to 2009, the percentage of women receiving doctoral degrees increased from 45% to 51% while the percentage of women receiving doctoral degrees in science and engineering increased half as much, from 38% to 41% (NSF, 2012). For all science doctoral degrees, the increase was even smaller, from 34% to 36%, while the increases in physical science and chemistry doctorates were both 5%, rising from 26% to 31% for physical science and from 34% to 39% for chemistry (NSF, 2012). The largest increase in doctoral degrees for women in science during this time was in biological sciences, with an increase from 44% to 52% (NSF, 2012).

Table 1: Percentages of Doctoral Degrees Awarded to Women, 2001-2009

	2001	2003	2005	2007	2009
Physical Sciences	26%	28%	27%	30%	31%
Chemistry	34%	33%	35%	37%	39%
Biological Sciences	44%	46%	49%	49%	52%

(NSF, 2012)

The under-representation of women in STEM presents a loss of talent and skilled labor, the exclusion of knowledge unique to women (such as agricultural and medicinal knowledge in many regions), and material resources women maintain (such as strain seeds in many regions; World Intellectual Property Organization, 2006). Gender biases in society play out through gender biases in STEM knowledge and research, reducing the benefits of STEM knowledge and research to society (Schiebinger, 2010). For example, automobile crash tests are performed with mannequins that are average male height and shorter drivers, including most women, are subsequently more likely to be injured in accidents (Hallman, Yoganandan, & Pintar, 2008).

Approaches to gender inequalities.

Since the 1970's, three distinct theoretical approaches to understand and diminish gender inequalities in STEM have been used (Schiebinger, 2010). The gender-neutral approach was introduced in the 1970's and advocates for equal access for females to STEM education and employment and assumes that STEM knowledge is objective, universal, and unbiased (Schiebinger, 2010). This assumption leads to the further assumption that STEM is gender neutral and causes gender differences to be ignored and focuses on problems in female representation in STEM being a result of attributes of women and not from other sources (Schiebinger, 2010).

The difference approach was introduced in the 1980's and emphasizes gender differences, identifies biases in STEM by researching and identifying omissions related to females, and encourages the use and examination of indigenous and traditional knowledge from non-Western cultures (Schiebinger, 2010). This approach has a tendency to play to conventional gender stereotypes because it romanticizes and generalizes traditional masculinity and femininity (Schiebinger, 2010). This romanticism and susceptibility to stereotyping leads to a failure to account for the range of perspectives and values men and women hold across cultures and tends to lead to "positive stereotyping," such as all women being nurturing (Schiebinger, 2010). The difference approach also focuses on women as change agents and fails to include men as potential change agents (Schiebinger, 2010).

Beginning in the 2000's, the "equality approach through gender analysis" was developed (Schiebinger, 2010). This approach uses gender analysis to enhance scientific research and focuses on mainstreaming gender analysis in STEM research (Schiebinger, 2010). The equality approach also disregards the assumption that increasing female participation in STEM will lead to gender inclusion, but instead insists that males must also be trained in the equality approach as part of the mainstreaming of gender analysis and the reform of STEM institutions and methods (Schiebinger, 2010).

Stereotype threat.

Stereotypes that men are more talented at and more interested in STEM fields are thought to influence the gender inequalities in these fields (Nosek et al., 2009). Women who endorse these stereotypes report lower interest in STEM fields and are

less likely to pursue a math or science degree (Nosek et al., 2009). Reminding women of the stereotype or sometimes even just unobtrusively reminding women of their gender can be sufficient to weaken their performance on tests (Nosek et al., 2009). Researchers have described this effect as stereotype threat and have theorized it to be the result of anxiety, specifically anxiety-related increases in cognitive load from the fear that one's behavior could confirm a stereotype about one's social group (Nosek et al., 2009).

A reverse scenario to stereotype threat has been demonstrated in studies with gender representation in STEM groups (Nosek et al., 2009). In one study, women science majors had lower feelings of belonging, reported lower desire to participate, and displayed enhanced threat-related physiological markers when they watched a conference video with 75% male participants than women science majors who watched a video with a gender-balanced group (Murphy, Steele, & Gross, 2007). In STEM fields, men greatly outnumber women and this situation is likely to be noticed and to affect prospective women scientists (Murphy, Steele, & Gross, 2007).

Summary.

While gender stereotypes with respect to STEM fields are well-documented and gender misrepresentation continues in the majority of countries and fields with STEM, few people explicitly endorse these stereotypes and misrepresentation (Nosek et al., 2009). Given the opposing influences of social identity threat and gender representation and the emerging equality approach using gender analysis, research on science instruction can use gender analysis to evaluate which influence is greater and

how males and females respond differently to interventions in science instruction (Nosek et al., 2009; Schiebinger, 2010).

Personalization (You) Effect.

One way to address under-performance by female students and also to improve student learning outcomes in multimedia learning materials for all students is to make use of the Personalization Effect (you; Mayer, 2009). The Personalization Effect (you) refers to the change in language from formal third person language to personalized language that includes informal first and second person pronouns (we and you) that directly addresses the learner (Mayer, 2009). An example of a traditional formal script without personalization (you) is:

In very rainy environments plant leaves have to be flexible so that they are not damaged by the rainfall. What really matters for the rain is the choice between thick leaves and thin leaves.

When the same script is personalized (you), the result is:

This is a very rainy environment and the leaves of your plant have to be flexible so they're not damaged by the rainfall. What really matters for the rain is your choice between thick leaves and thin leaves.

The Personalization Effect (you) has been demonstrated in three subject areas, lightning generation (Moreno & Mayer, 2000), plant physiology (Moreno & Mayer, 2000 & 2004), and lung physiology (Mayer, 2004). The effect has been observed with instructional videos of 60 seconds (Mayer et al., 2004) and 140 seconds (Moreno & Mayer, 2004) and with instructional computer-based games of 14 to 16 minutes (Moreno & Mayer, 2004) and 24 to 28 minutes (Moreno & Mayer, 2000). The effect

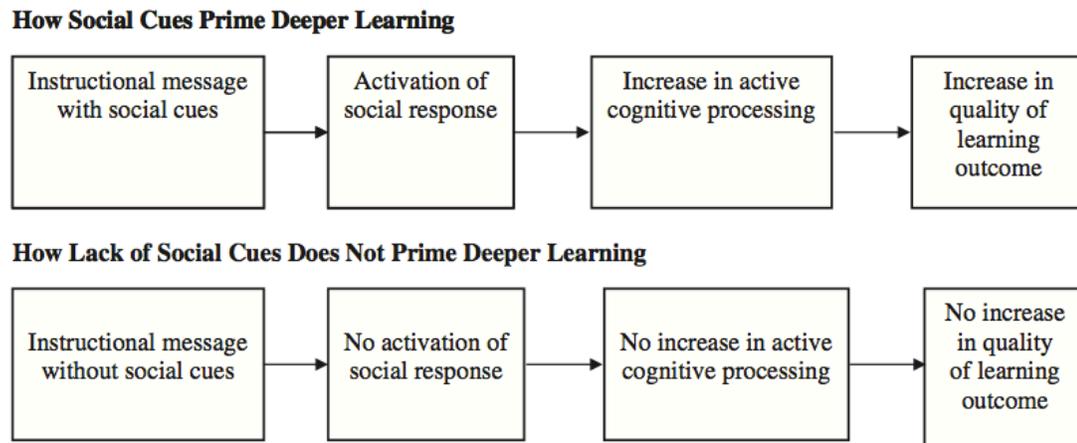
has not been studied with longer instructional videos or with shorter length instructional games. The effect has been studied with respect to learning outcomes and variables intended to shed light on social agency theory, the theory that attempts to explain how personalization and similar effects work (Moreno & Mayer, 2010).

The learning outcomes have been divided into test items that focus on the recall of basic facts, called retention measures, and the ability to apply the knowledge from learning to novel situations, called transfer measures (Moreno & Mayer, 2010). Improvements in retention have been inconsistent across studies, ranging from statistically not significant to medium effect sizes (Moreno & Mayer, 2000 & 2004; Mayer, 2004). Improvements in transfer with personalization have been more consistent across studies, ranging from medium to large effect sizes (Moreno & Mayer, 2010).

Personalization and Social Agency.

In addition to measuring improvements in learning, attempts have been made to measure other effects to shed light on Social Agency Theory, which attempts to explain the Personalization Effect (you; Moreno & Mayer, 2000 & 2004; Mayer, 2004). Social Agency Theory posits that including the pronouns we and you constitute social cues that activate a social response in the learner leading to increased cognitive processing and subsequent increases in the quality of learning outcomes (Mayer, 2009). Figure 1 shows that while the social cues lead to social response, the lack of social cues in traditionally phrased learning materials fails to do so (Mayer, 2009).

Figure 1: Social Agency Theory



(Mayer, 2009).

Attempts to measure social agency effects in personalization (you) studies have proved more inconsistent (Moreno & Mayer, 2010). In the 2000 study, Moreno and Mayer included a variable called program rating that consisted of a combination of eight items that measured participants' motivation, interest, and understanding as well as the perceived difficulty of the material and the friendliness of the program. Results for the program ratings were not statistically significant, but trended in the direction favoring personalization and the result for experiment 4 was almost statistically significant. Mayer has continued to attempt to measure several of the components of program rating in subsequent studies to elucidate how social agency theory operates (Moreno & Mayer, 2000 & 2004; Mayer, 2004). Ongoing measures have included interest, difficulty, and friendliness. The understanding item about helpfulness has continued to be used, but as an indicator of perceived helpfulness of the program and not of learner understanding.

Summary.

The three major studies on the personalization (you) effect consistently show medium to large effect sizes for increases in transfer outcomes using personalized language compared to traditional language (Moreno & Mayer, 2000 & 2004; Mayer, 2004). Retention outcomes are more mixed, ranging from statistically not significant to medium effect sizes. Measures of social agency and perceived difficulty are similarly mixed, ranging from statistically not significant to medium effect sizes. Additional measures of retention and social agency are needed to more closely examine how social agency works and to further develop Social Agency Theory.

Exploring Personification.

While the personalization (you) studies have used language where traditional language is changed from being impersonal to using first and second person language (we and you) to prime a social response (Moreno & Mayer, 2000 & 2004; Mayer, 2004), the possibility has been unexplored as to whether or not changing traditional language in multimedia learning materials to refer to objects under study as she or he could also prime such a response. This unexplored effect is called the personification (s/he) effect in this dissertation and to assist in distinguishing it from personalization (you), pronoun indicators are used: personalization (you) versus personification (s/he).

One example of personification (s/he) can be constructed from Moreno and Mayer's 2004 study using a plant physiology lesson, building on the example of personalization (you). The example script from the original version with neither personalization (you) nor personification (s/he) used earlier is:

In very rainy environments plant leaves have to be flexible so that they are not damaged by the rainfall. What really matters for the rain is the choice between thick leaves and thin leaves.

The same example with personalization (you) is:

This is a very rainy environment and the leaves of your plant have to be flexible so they're not damaged by the rainfall. What really matters for the rain is your choice between thick leaves and thin leaves. Which do you think would be more flexible?

When the same script is personified (s/he), one possibility is:

A plant in a very rainy environment needs to have leaves that are flexible so that her leaves are not damaged by the rainfall. What really matters for the plant in the rain is whether she has thick leaves or thin leaves. Which is more flexible for her?

Exploring personification (s/he) should include measures of retention (recall of information) and transfer (application of information and problem-solving) since such effects have been observed in personalization (you) studies (although not consistently across all of the studies). Including measures of social agency to evaluate how such an effect might be priming a social response are likely to provide mixed or limited results given the mixed and limited results from personalization (you) studies.

This study compared four treatments with personalization (you) only, female personification (she) only, and male personification (he) only, against a traditional treatment with neither personalization (you) nor personification (s/he). In addition to

comparing the effects of personalization (you) and personification (s/he) separately, two treatments are included that combine personalization (you) and personification (s/he) together. Using both changes can result in a treatment with larger effect sizes than either personalization (you) or personification (s/he) alone. A treatment combining personalization (you) and personification (s/he) could look like the following example:

When your plant is in a very rainy environment, she needs to have leaves that are flexible so that they are not damaged by the rainfall. What really matters for your plant in the rain is whether she has thick leaves or thin leaves. Which do you think is more flexible for her?

Since the combined treatment could use masculine or feminine pronouns, this added two additional treatments to the study, namely personalization (you) and female personification (she) and personalization (you) and male personification (he).

Personification (s/he) and learner gender.

Given that personification (s/he) is not gender neutral, there is the potential for a gender interaction effect between the gender of the students (males and females) and the gender used in personified (s/he) learning materials (he and she). Gender analysis was used to determine that there is an interaction.

Personification (s/he) and abstract learning materials.

The three studies on personalization (you) have involved concrete subject matter that can be visually experienced using the naked eye or microscopes, namely clouds and lightning (Moreno and Mayer, 2000), plant physiology (Moreno and Mayer, 2000 & 2004), and lung physiology (Mayer et al., 2004). None of these

studies have involved subject matter that is abstract and cannot be seen, such as quantum mechanics, string theory, or the electronic structure of atoms. This study explored whether personalization (you) was useful for students studying abstract learning material. Likewise, personification (s/he) was explored to determine if it is useful for students studying abstract learning material. Given that studies have not examined the use of personalized (you) or personified (s/he) language in the study of abstract subjects using multimedia learning materials, it is worth determining whether such language treatments make a difference.

Current instructional materials in chemistry use formal third person language and gender neutral pronouns in describing models of the atom and electronic structure. This study was undertaken to determine if there are sufficiently strong learning improvements with personalized (you) and/or personified (s/he) language to recommend changing instructional materials to use he, she, you, and other personal pronouns.

Furthermore, the study was undertaken to evaluate extending personalization (you) and adding personification (s/he) for use with abstract subject matter and to potentially extend or expand social agency theory itself by providing new settings in which to investigate how social agency operates.

Theoretical Background

Cognitive Load Theory.

The proposed study on personalization (you) and personification (s/he) has as its foundation three different theories, the first of which, Cognitive Load Theory, focuses on the impact new information makes on working memory. Miller put forth

the idea that working memory has limited capacity (Miller, 1956). This idea was developed more specifically to state that the capacities to hold and process information are limited (Baddeley, 1986; Baddeley and Hitch, 1974). From these ideas, Cognitive Load Theory was developed as a framework for instructional designers so that they might optimize learning during instruction (Sweller, 1988; Chandler and Sweller, 1991).

Cognitive Load Theory posits that learners have a limited amount of working memory available and that the “load” or amount of memory required to learn different materials varies (Chandler and Sweller, 1991). Cognitive Load Theory divides the working memory requirements of learning into three types: extraneous load, intrinsic load, and germane load. As its name implies, extraneous load is not necessary for learning and can reduce the ability of learners by using memory that could otherwise be used for intrinsic or generative load. Intrinsic load is the memory requirement for selecting, organizing, and understanding learning material. Germane load is the memory requirement for integrating new knowledge with existing knowledge.

Since the development of Cognitive Load Theory, the language of memory has shifted from describing load and memory requirements to a language of processing with a focus on mental activities involved in learning (Mayer & Moreno, 2010). In this shifted language, extraneous processing refers to mental activities necessitated by any extraneous load in the learning materials and/or methods of instruction (Mayer & Moreno, 2010). This extraneous processing adds no new information to the subject under study. The mental capacity used for extraneous

processing could be more productively directed towards processing germane load (Mayer & Moreno, 2010). Learning can be made more effective and efficient by reducing or eliminating extraneous processing (Mayer & Moreno, 2010).

Reducing extraneous processing can be as simple as removing distracting non-essential elements from a diagram. Another example of the reduction of extraneous processing is signaling (Mayer & Moreno, 2010). Signaling uses visual and/or verbal clues, such as headings, outlines, and intonations, to indicate where learners should direct their attention so that learners do not use memory for selecting what material to focus on and can use more memory for intrinsic and generative processing.

The other memory requirements of learning materials are intrinsic processing (organizing and forming mental representations) of material to be learned and generative processing (integrating new knowledge). Intrinsic processing supports learning objectives and involves the organization of learning material and the formation of mental representations of the material. Generative processing also supports learning objectives and involves the integration of the subject material with prior knowledge.

Intrinsic processing depends on the difficulty level of the learning material itself that results from the complexity or unfamiliarity of the material or the speed at which it is presented (Moreno & Mayer, 2010). The complexity level is a result of the number of elements that must be held in working memory at one time in order to understand and learn the material (Sweller, 1999). Consider a lengthy stepwise procedure such as a long recipe. While there are many steps in such a recipe, because the steps do not all have to be held in memory at one time, the lengthy recipe would

not be as difficult to learn as creating a structural formula in chemistry. Creating a structural formula in chemistry requires a learner to hold information about all the atoms in a molecule and how those atoms are bonded to each other in working memory all at the same time. The large number of interacting elements that must be held in working memory all at the same time make the learning material much more difficult and require much more intrinsic processing than learning materials with fewer elements or with elements that do not have to be remembered all at once.

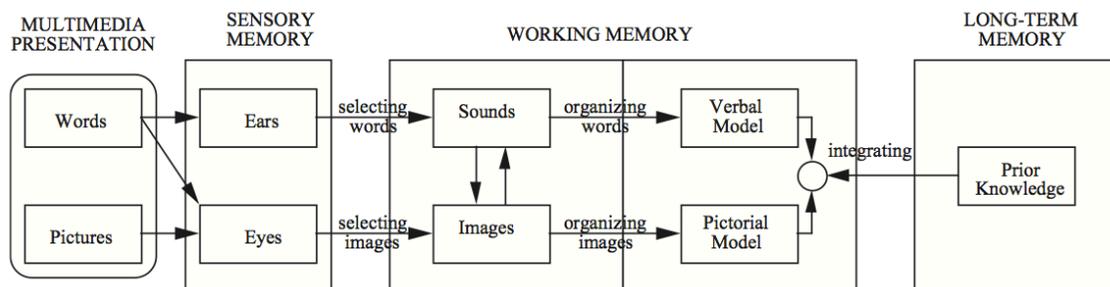
A second approach to increase learning outcomes is to assist learners in managing intrinsic processing (Mayer & Moreno, 2010). In other words, the approach is to assist learners in the management of the intrinsic load to make difficult material easier to learn processing (Mayer & Moreno, 2010). An example of this approach is segmenting (which was not used in this study), where complex material is presented in meaningful segments with the pacing under the learner's control, but not all of the material at once processing (Mayer & Moreno, 2010).

The promotion of generative processing is a third approach to increase learning outcomes (Moreno & Mayer, 2010). An example of this approach is the guided activity. One such activity consists of asking students to engage in problem solving with a pedagogical agent. Learners receive guidance about their actions during learning and interact with the pedagogical agent. Interactivity and feedback are the central features of guided activities that promote the integration of new learning with existing prior knowledge.

Cognitive Theory of Multimedia Learning.

The second theory that underlies the proposed study is the Cognitive Theory of Multimedia Learning (CTML, Mayer 1997), which combines the idea of limited working memory capacity (Baddely, 1986; Baddeley & Hitch, 1974; Miller 1956) with Cognitive Load Theory (Sweller, 1988; Chandler and Sweller, 1991) and dual coding theory (Paivio, 1986). CTML posits that the visual and verbal channels for information processing are distinct and separate processing channels in working memory. Figure 2 highlights the verbal and visual channels in CTML and how information is processed separately in the channels before being combined and organized into mental representations and integrated with prior knowledge (Mayer, 2008).

Figure 2: Cognitive Theory of Multimedia Learning



Designing instructional materials that distribute information between the two channels produces materials that are less likely to overload the learner's cognitive capacity (Mayer & Moreno, 2010). Multimedia learning materials are an example of such materials that use audio and images to access both channels during learning.

There are three major assumptions in CTML (Mayer, 2008). First is the dual-channel assumption that separate channels or pathways process verbal and visual information (Mayer, 2008). Second not only does total working memory have limited

capacity, but each channel also has a separate and distinct limited capacity (Mayer, 2008). Third is that working memory attempts to integrate information from each channel into a coherent mental representation, referred to as active processing (Mayer, 2008).

CTML details the steps learners follow in processing verbal and visual information (Mayer, 2008). First, information is selected from visual and auditory displays (Mayer, 2008). Then the information is organized and processed into separate verbal and visual representations (Mayer, 2008). Finally those representations are integrated into existing knowledge. This integration is the building of schemas. Schemas are built upon each other and new knowledge is continually integrated with existing knowledge in the process of learning (Mayer, 2008).

One approach to developing multimedia materials based on CTML has been to reduce the cognitive load from extraneous processing so that more working memory can be devoted to essential processing (Mayer, 2009). Reducing extraneous processing can be as simple as removing non-essential details from a diagram, video, or explanation. The signaling principle demonstrates another approach to reduce extraneous processing (Mayer, 2005). The signaling principle states that providing guidance for learners to direct their attention results in increased learning (Mayer, 2005). Signaling in text is done by highlighting essential words and sentences, using bold fonts, using italics, and underlining (Mayer, 2009). In narrations, the effect is achieved through spoken emphasis (Mayer, 2009). Directing learners to relevant information reduces the need for learners to examine text or narration to determine

where to focus their attention so that the working memory required for this examination and selection can instead be used for processing the intrinsic and generative load of the learning material (Mayer, 2009).

A second approach to increase learning outcomes is to help learners manage intrinsic load (Mayer & Moreno, 2010). An example of this is pre-training, where learners are trained in the names and elements of the learning materials before formally viewing the presentation in their studies (Mayer & Moreno, 2010). Pre-training helps students to organize the material and to generate mental representations of the material under study (Mayer & Moreno, 2010).

A third approach is to increase generative processing (Mayer, 2009). A specific example of this is the personalization (you) effect, which may work by increasing personal interest and personal relevance, and thereby social agency (Mayer, 2009). In the personalization effect, first and second person personal pronouns (we and you) are used to indicate direct connections between the learner and the subject matter (Mayer, 2009). These connections are posited to elicit increased generative processing that leads to increased retention and transfer (Mayer, 2009).

From CTML, Mayer (2005a, 2009) has identified, studied, and explained numerous effects and design principles to improve learning outcomes with multimedia instructional materials. The design principles based on these effects will be used in this study to ensure that the multimedia instructional chemistry videos do not increase extraneous processing and so that they help students to manage essential processing. This study will examine whether learning outcomes are increased

through personalization (you) and personification (s/he), both separately and in combination.

Based on previous studies, the personalization (you) effect is theorized to enhance intrinsic and generative processing in learners (Moreno & Mayer, 2000 & 2004; Mayer, 2004 & 2009). The personalization effect is one of several effects that have in common a relation to human social characteristics (Mayer, 2009). These effects are explained by Social Agency Theory.

Social Agency Theory.

The third theory which underlies the proposed study, Social Agency Theory, explains the effects identified in multimedia learning studies that increase essential and generative processing through social cues (Mayer, 2009). Social Agency Theory posits that social cues prime a social response in learners that leads to increased essential and generative processing (Mayer, 2009). In the personalization (you) effect, the social cues used most commonly are first and second person personal pronouns (we and you), which indicate direct connections between the learner and the subject matter (Mayer, 2009). The social response in learners then leads to increased active cognitive processing and a subsequent increase in retention and transfer learning outcomes (Mayer, 2009). This social response is possible because people can readily accept computers as social partners (Reeves & Nass, 1996).

The social response can be primed through the use of conversational language using first and second person pronouns (you and we), called personalization (Mayer, 2009). Social response can also be primed by promoting autonomy and approval (the politeness effect) and by using human voices instead of computer-generated voices

(the voice effect) (Mayer, 2009). Social response does not improve when an image of the speaker is visible on screen (the image effect; Mayer, 2009).

Social Agency Theory posits that once the social response is primed, active processing increases, similar to the cooperation effect in inter-human communication (Mayer, 2009). In the cooperation effect, people assume an implicit agreement between the speaker and the listener where the listener works to understand the speaker, who works to be informative, relevant, accurate, and concise (Grice, 1975). In the multimedia setting, the cooperation effect may be induced when learners accept computers as social partners (Mayer, 2009). Then learners may assume the role of listener and work harder to understand the speaker/computer that delivers the learning material (Mayer, 2009).

The increase in effort and processing can then result in increased retention (recall of information) and greater ability to transfer learned material to different settings (applications and problem-solving; Mayer, 2009). When humans work harder to understand a human speaker (or learners work harder to understand a computer regarded as a social partner), they engage in five activities identified in CTML: selecting words, selecting images, organizing words, organizing images, and integrating the words and images into long-term memory (Mayer, 2009). Increasing these specific activities results in overall increased essential and generative processing which in turn results in improved retention and transfer (Mayer, 2009).

Social Agency Effects.

The four social agency effects that have been studied to date are the voice effect (Mayer, 2009), the image effect (Mayer, 2009), the politeness effect (Wang et al., 2008), and the personalization effect (Mayer, 2005).

The first social agency effect is the voice effect (Mayer, 2009). The Voice effect describes the effect of using narration with a native English speaker using a standard accent and friendly tone compared to narration from a high quality speech synthesizer. The three studies of the voice effect have yielded results that favor the human voice over machine voice with effect sizes from 0.69 to 0.79

A second social agency effect is the image effect, where the instructor's image is visible on screen (Mayer 2009). Five studies were performed to evaluate this effect with four of the studies using an animated character and one study using a non-animated human character. The effect sizes for the five studies were inconsistent and weak, ranging from -0.50 to 0.35, with a median value of 0.22. "People do not necessarily learn more deeply from multimedia lesson when the speaker's image is added to the screen (Mayer 2009)."

A third social agency effect is the politeness effect (Wang et al, 2008; McLaren, DeLeeuw & Mayer 2011). The politeness effect was studied in two studies of online tutors used to help students develop problem-solving skills. In the politeness effect, social language using first and second person personal pronouns along with polite vocabulary and phrasing is used. This language was used to indicate connections between the learner and the subject matter and to induce a social response that is theorized to increase intrinsic and generative processing. Politeness

works by increasing learners' senses of autonomy (technically described as minimizing negative face) and approval (technically described as increasing positive face). The effect size for the first experiment conducted on the politeness effect was 0.71. For the second study the effect size was 0.78 on an immediate test and 0.51 on a delayed test for learners with low prior knowledge of the subject material. (Learners with high prior knowledge showed the reverse effect with -0.47 effect size immediately and -0.13 on a delayed test.)

A fourth social agency effect that has been studied is the personalization (you) effect. The personalization effect has been reported in three research papers (Moreno & Mayer, 2000 & 2004; and Mayer et al., 2004). In the personalization effect, the script of the audiovisual learning materials is changed from a traditional third person style to include second person pronouns to directly address the learner as "you." Personalization is hypothesized to induce a social response by mimicking human conversation and that results in learners working harder (fostering greater generative processing) to understand and learn the subject material (Mayer, 2009). Personalization has been studied in the subject areas of lightning generation, plant physiology, and lung physiology. Effect sizes for transfer items (measuring application and problem solving with learned material) in these studies have ranged from medium to large effect sizes (Moreno & Mayer, 2010).

A fifth social agency effect, which has not yet been studied or reported is the personification (s/he) effect. This effect could foster generative processing and improved learning for students by describing non-human learning objects (such as

atoms) as she's or he's, thereby personifying those learning objects to induce a social response from the learners.

Purpose of the Study

The purpose of this study is to examine if personification (s/he) of learning materials elicits a social response and increases learning and if it presents any interactions based on the gender of the language and the gender of the student. The study will examine increases in learning in both retention (factual recall) and transfer (problem solving and application of knowledge) since other social effects have shown improvements in both types of learning, although improvements in retention have been less consistent. Furthermore, this study will examine if there is an interaction between personalization (you) and personification (s/he) by using six treatments:

- 1) a control with traditional formal instructional language using only neutral third person pronouns (such as it, its, they, and their),
- 2) a treatment with personalization (you) incorporating direct second person personal pronouns (such as you, your, and yours),
- 3) a treatment with personification (s/he) only incorporating male third person pronouns (such as he, him, and his),
- 4) a treatment with personification (s/he) only incorporating female third person pronouns (such as she, her, and hers),
- 5) a treatment with both personalization (you) and male personification (he), and
- 6) a treatment with both personalization (you) and female personification (she).

In addition to examining personalization (you) and personification (s/he), this study will examine if there is a gender interaction between the treatment personification

(s/he) gender and the learner's gender with respect to the outcome variables and measures of stereotype threat and gender representation response.

Research Questions

The research questions are:

1. What are the effects on student learning (retention/recall and transfer/problem-solving and application) when learning materials are changed from traditional language to language that is personalized (you), personified (s/he), or both?
2. To what extent do the six treatment conditions create stereotype threat conditions for participants? For example, do females in the personified male (he) treatment group have lower scores than males in the same treatment group?
3. To what extent do females or males in any of the treatment conditions perform better than in the other conditions? For example, do females in the personification female (she) treatment group perform better than females in the personification male (he) treatment group?

Summary

Chemistry is a complex and difficult subject area for learners in general and the gender inequality in science indicates a need for gender analysis of learning treatments (Drew, 2011; Schiebinger, 2010). Multimedia learning materials offer a way to help students reduce extraneous processing and to manage essential processing with complex learning tasks like those in chemistry (Mayer, 2009). Social agency effects offer a way to improve learning outcomes by triggering a social response in learners by using social cues (Mayer, 2008). Personalization (you) has been used to effect a social response in learners (Moreno & Mayer, 2000, 2004;

Mayer, 2004). Personification (s/he) can offer another method for eliciting a social response in learners and can also have a synergistic effect when used in concert with personalization. Personification (s/he) (with or without personalization (you)) can also produce a gender interaction since female and male learners may have different outcomes when using personified (s/he) learning materials that have female or male pronouns. Gender interactions may be the result of students responding to gender inclusion and representation or stereotype threat (Nosek, 2009).

Definitions of Terms

Cognitive Load Theory: A learning theory that is based on the assumption that a human's working memory has only a limited capacity to store information.

Cognitive load theory describes the distribution of working memory resources during the learning process (Sweller, 1988).

Cognitive Theory of Multimedia Learning: A learning theory based on the assumption that people possess dual channels for processing verbal and visual information, that each channel is limited in how much information it can process, and that meaningful learning involves engaging and actively processing information appropriately (Mayer, 2001).

Dual Coding Theory: A learning theory that is based on the assumption that both visual and verbal information is processed along different channels in the brain (Paivio, 1986).

Essential Processing: The cognitive processing that is required to make sense out of words and pictures needed to achieve an instructional objective (Mayer, 2005a).

Extraneous Processing: Cognitive processing that is not required to make sense out of words and pictures needed to achieve an instructional objective, but is a result of elements of instructional materials that do not support the learning objective (Mayer, 2005).

Generative Processing: Cognitive processing involved in integrating new learning with prior knowledge (Mayer, 2009).

Multimedia: A form of communication that uses words and pictures to foster meaningful learning (Mayer, 2001).

Personalization Principle: An instructional design principle that states that people learn more from multimedia when the narration addresses the learner directly using language that includes words like you and your (Mayer, 2009).

Personification Effect: The effect on learning of describing objects under study using the pronouns she and/or he, and the various forms of these third person gender-specific pronouns (her, his, hers, him, et al.) where learners may learn more from multimedia when these pronouns are used. Personification may present an interaction where the use of female or male pronouns (she versus he) may result in an interaction with the learner's gender (female versus male students) where learning improvements for students of each gender are different with she or he.

Social Agency Theory: A theory that social cues present in multimedia learning materials produce a social response from learners that leads to increased cognitive processing and improved learning (Mayer, 2009).

Working Memory: A limited and multifaceted cognitive information storage and processing system (Baddeley, 1986).

Chapter 2

Review of the Literature

This review of the literature describes the Cognitive Theory of Multimedia Learning (CTML), including principles known to affect learning. These principles will be applied in the design of treatments for the proposed study. As well, CTML effects that are similar to personalization (you) and personification (s/he) are described for comparison purposes. Social Agency Theory, which is used to explain how personalization (you) and similar effects work, is also described. Then the personalization effect is described in detail from the perspective of Social Agency Theory. Finally, computer-based multimedia chemistry instructional materials are described for comparison to the current study as well as CTML and Social Agency Theory.

Principles of the Cognitive Theory of Multimedia Learning and Their Application to Multimedia Learning Materials

Mayer's Cognitive Theory of Multimedia Learning (CTML, Mayer 1997) was based on Sweller's Cognitive Load Theory (Sweller, 1988; Chandler and Sweller, 1991), but also incorporated Paivio's Dual Coding Theory (Paivio, 1986) to explain how audio and visual mental processing correspond to and work with the audio-visual presentation of learning materials. CTML also allows for multimedia learning principles to be divided into three groups based on how they function: principles that reduce extraneous processing, principles that help manage essential processing, and principles that foster generative processing. The following sections describe these functions and the principles that correspond to each function type and which

principles were incorporated into the design of the multimedia learning materials used in this study.

Dual channels.

CTML posits that sensory input in learning is predominately done through auditory and visual processing (Mayer, 2009). Information presented to the eyes is processed through the visual channel. Such information includes, pictures, animations, and text. Information presented to the ears is processed through a separate auditory channel and includes both words (narration) and non-verbal sounds. Dual channels are closely associated with Paivio's Dual Coding Theory (1986) and Baddeley's model of working memory (Baddeley, 1974, & Baddeley & Hitch, 1986).

Limited memory capacity.

The first assumption in CTML is that working memory has limited capacity (Miller, 1956; Baddeley, 1986). While there is limited total capacity for working memory, there is also limited auditory capacity and a separate and distinct visual capacity (Paivio, 1986). That is, each processing channel for processing sensory input has its own memory capacity (Mayer, 2009; Baddeley, 1986). When working memory demands for either channel is exceeded, then learning is hindered (Mayer, 2009). When learning materials are presented in one format only (all visual or all auditory), then the limit for the amount of material that can be learned without hindrance is equal to the memory capacity of that channel (Mayer, 2009; Baddeley, 1986). For example, material presented in a lecture (auditory format) cannot exceed the memory capacity of the auditory processing channel without hindering learning. But if that material is divided so that some of the lecture material is presented visually

(using a picture or narration) then additional auditory material can be presented without exceeding auditory processing channel capacity. While the use of auditory and visual processing allows for processing of more material than either channel alone, the use of the two channels still does not allow for processing more than the total limited working memory capacity (Mayer, 2009; Baddeley, 1986).

Extraneous, essential, and generative processing.

Not only does memory capacity divide into auditory and visual capacity, but capacity is split among three types of active processing: extraneous, essential, and generative (DeLeeuw & Mayer, 2008).

Extraneous processing is mental processing that is not essential for learning and can and should be reduced through better-designed learning materials (Sweller, 1999; Mayer, 2009). An example of this is the use of background music or sound effects in multimedia materials (Mayer & Moreno, 2010). Removal of this material from multimedia instructional materials resulted in improved learning outcomes. The unnecessary music and sound effects increased the cognitive load of the learning material and caused the learner to engage in extraneous processing, which decreased the amount of essential and generative processing the learner could engage in (Mayer & Moreno, 2010).

Essential processing is the processing which must occur in learning new material and which has been thought to be irreducible by instructional design (Sweller, 1999; Mayer, 2009). Recent research has indicated that this is not necessarily the case as pre-training and other methods can help learners manage cognitive load and engage in more effective (and lower levels of) essential processing (Mayer, 2009;

Musallam, 2010). Pre-training is when a learner is introduced to vocabulary and concepts of the learning material before studying the learning materials to help the learner manage the material (Musallam, 2010).

Essential processing leads to generative processing where the learner constructs a coherent mental representation of the newly learned material and connects it to prior knowledge (Sweller, 1999; Mayer, 2009). Generative processing is desirable and can be increased through instructional design (Moreno & Mayer, 2010).

Research into improving the design of multimedia learning materials can be grouped into three categories that correspond to the three types of mental processing (Mayer, 2009). The first category is research on the reduction of extraneous processing, a desirable outcome given that extraneous processing is undesirable as it impedes learning (Mayer, 2009). The second category is the management of essential processing. Essential processing was previously thought to be irreducible, but more recent research has found ways to help learners manage (and possibly reduce) essential processing (Mayer, 2009). The third category focuses on the desirable generative processing and ways to promote it (Mayer, 2009).

Principles for reducing extraneous processing.

Instructional design should be sensitive to the memory capacity of learners and it is important not to exceed this capacity (Sweller, 1999; Mayer, 2009). Capacity can be exceeded easily by including too much extraneous material or by presenting material in ways that are confusing for learners (Sweller, 1999; Mayer, 2009). When memory capacity is exceeded, or when too much capacity is devoted to

extraneous processing, there is insufficient capacity left for essential and generative processing (Sweller, 1999; Mayer, 2009). As a result, learning suffers. Five principles have been identified to help reduce extraneous processing for learners. All five principles were followed in the construction of multimedia learning materials for this study and verified by content reviewers using the video content expert rating sheet included as Appendix D and described in chapter three.

Coherence principle.

The coherence principle refers to the exclusion of extraneous information from learning materials and a focus on conciseness rather than on elaboration (Mayer & Moreno, 2010). Four experiments have examined the effects on post-test scores of removing extraneous information, such as removing unnecessary video clips (Mayer, Heiser, & Lonn, 2001), removing background music and sound effects (Moreno & Mayer, 2000), and removing formulas and numerical calculations from an elaborate explanation (Mayer & Jackson, 2005). The effect sizes have ranged from 0.51 for removing background music and sound effects in a lesson on brakes to 1.49 for removal of background music and sound effects in a lesson on lightning. The median effect size for the four reported experiments on coherence is 0.70. The experiments on coherence and the effect sizes are summarized in Table 5.

Table 2: Summary of Coherence Principle Experiment Results

Modification	Content	Effect size	Source
Removal of background music and sound effects	Lightning	1.49	Moreno & Mayer, 2000
Removal of background music and sound effects	Brakes	0.51	Moreno & Mayer, 2000

Removal of unnecessary video clips	Lightning	0.70	Mayer, Heiser, & Lonn, 2001
Removal of formulas and numerical calculations	Ocean waves	0.69	Mayer & Jackson, 2005
Median		0.70	

Redundancy principle.

The redundancy principle is another way to improve instructional material—this time by removing redundant text from narrated learning materials (Mayer & Moreno, 2010). Adding on-screen text to narrated instructional materials would seem to provide an additional way to learn material and to allow learners to follow their preference for reading or listening to the material (Mayer & Moreno, 2010). But empirical evidence has shown that the inclusion of redundant on-screen text leads to reduced performance on post-treatment tests (Craig, Gholson, & Driscoll, 2002; Mayer et al., 2001; Moreno & Mayer, 2002). This may not be the case for situations where learners are non-native speakers or learners are hearing-impaired, but there have been no studies to evaluate these possible exceptions (Mayer & Moreno, 2010).

Redundant on-screen text is thought to increase extraneous processing because learners process both the auditory narration and the visual text in addition to visual images and visual videos that are part of the multimedia learning materials (Mayer & Moreno, 2010). On-screen text can be doubly problematic because text is thought to require processing in both the visual and auditory processing channels (Mayer, 2009). In short, reading the text requires visual processing, but the words are still “heard” inside the mind where auditory processing is required to make sense of the text. Removing the redundant text frees the auditory channel to focus on

processing the narration and the visual channel to focus on images and videos (Mayer & Moreno, 2010).

Eight experiments have demonstrated the redundancy principle. Two experiments by Kalyuga, Chandler, and Sweller (1999, 2000) with electrical engineering multimedia learning materials yielded effect sizes of 1.38 and 0.86. Four experiments on lightning (Mayer, Heiser, & Lonn, 2001; Craig, Gholson, & Driscoll, 2002; Moreno & Mayer, 2002) yielded effect sizes of 0.88, 1.21, 0.67, and 0.72. Moreno and Mayer (2002) conducted two experiments with an environmental science game that also confirmed the redundancy effect with smaller effect sizes of 0.19 and 0.25.

Table 3: Summary of Redundancy Principle Experimental Results

Content	Effect size	Source	Experiment
Electrical engineering	1.38	Kalyuga, Chandler, & Sweller, 1999	1
Electrical engineering	0.86	Kalyuga, Chandler, & Sweller, 2000	1
Lightning	0.88	Mayer, Heiser, & Lonn, 2001	1
Lightning	1.21	Mayer, Heiser, & Lonn, 2001	2
Lightning	0.67	Craig, Gholson, & Driscoll, 2002	2
Lightning	0.72	Moreno & Mayer, 2002	2
Environmental science game	0.19	Moreno & Mayer, 2002	2a
Environmental science game	0.25	Moreno & Mayer, 2002	2b
Mean	0.79		

Signaling principle.

Signaling can help learners reduce extraneous processing and can also help manage essential processing (Mayer & Moreno, 2010). Signaling consists of cues to direct the learner's attention to salient material and can be done verbally through intonation, pointer words, and spoken headings (Mayer & Moreno, 2010). Signaling can also be done visually using arrows or highlights, but no studies on visual signaling with multimedia learning materials have been published to date (Mayer & Moreno, 2010). Signaling reduces extraneous processing by preventing learners from focusing on non-essential aspects of learning materials and can help manage essential processing by reducing the work learners perform in selecting which parts of the learning materials to focus on (Mayer & Moreno, 2010).

Three experiments from only two studies provide evidence for the signaling principle. Two experiments by Mautone and Mayer (2001) on how airplanes achieve lift yielded effect sizes of 0.60 and 0.70 while Moreno and Abercrombie (2010) produced an effect size of 0.70 using signaling in the context of teacher education.

Table 4: Summary of Signaling Principle Experimental Results

Content	Effect size	Source	Experiment
Airplane	0.60	Mautone & Mayer, 2001	3a
Airplane	0.70	Mautone & Mayer, 2001	3b
Teaching principles	0.81	Moreno & Abercrombie, 2010	1
Median	0.70		

Temporal contiguity principle.

Extraneous processing can result from poorly laid out instructional materials. Mistiming of auditory and visual material, either by design or by accident, results in learners having to retain information from one source while also absorbing information from another source. Mayer and Moreno (2010) provide an example of an electronic car manual where clicking on one icon presents an audio explanation of how the braking system works while clicking on another icon presents an animation of how the braking system works. A better layout would have the audio and visual explanations complement each other in time so that the learner would not have to remember the entire verbal explanation when watching the animation, but could take in the auditory and visual information at the same time.

Eight experiments from four studies have provided evidence for the temporal contiguity principle with effect sizes ranging from 0.92 to as large as 2.22, and with a median size of 1.31. Mayer and Anderson reported two experiments in 1991 with effect sizes of 0.92 and 1.14 for multimedia learning materials on how tire pumps work. They again reported effect size for two more experiments in 1992 with effects sizes of 1.66 and 1.39 for experiments on how tire pumps and brakes work (Mayer & Anderson, 1992). Mayer and Simms reported effect sizes of 0.91 and 1.22 for experiments with learning material on how tire pumps work and lungs function (1994). Two other experiments demonstrating the temporal contiguity effect with effects sizes of 2.22 and 1.40 for learning materials on lightning formation and how brakes work (Mayer, Moreno, Boire, & Vagge, 1999).

Table 5: Summary of Temporal Contiguity Principle Experimental Results

Content	Effect size	Source	Experiment
Tire pump	0.92	Mayer & Anderson, 1991	1
Tire pump	1.14	Mayer & Anderson, 1991	2a
Tire pump	1.66	Mayer & Anderson, 1992	1
Brakes	1.39	Mayer & Anderson, 1992	2
Tire pump	0.91	Mayer & Sims, 1994	1
Lungs	1.22	Mayer & Sims, 1994	2
Lightning	2.22	Mayer, Moreno, Boire, & Vagge, 1999	1
Brakes	1.40	Mayer, Moreno, Boire, & Vagge, 1999	2
Median	1.31		

Spatial contiguity principle.

The spatial contiguity principle is similar to the temporal contiguity principle, but refers to contiguity of words and pictures. Lack of spatial contiguity occurs when learners have to search for and match mutually referring but spatially separated elements (Ginns, 2006). Spatial contiguity has been studied in only one study with multimedia learning materials, but has also been studied with numerous paper-based lessons and was referred to in many of these studies as the split-attention effect.

Moreno and Mayer (1999) conducted the one multimedia experiment on spatial contiguity, producing an effect size of 0.82 with learning materials on lightning. Ginns (2006) conducted a meta-analysis of previous studies on spatial

contiguity using paper-based lessons for 37 spatial contiguity experiments and found a standardized mean effect size of 0.72.

Principles for managing essential processing.

In addition to the preceding methods for reducing extraneous processing, learning can be enhanced by helping learners manage essential processing (Mayer & Moreno, 2010). By definition essential processing is thought of as the processing made by memory demands of content that is inherent to those materials. Essential processing consists of mentally representing the material so that it can be integrated with prior knowledge through generative processing (Mayer & Moreno, 2010). For truly complex learning materials, the elimination of extraneous processing may be insufficient for learners to have sufficient cognitive capacity for learning. This can be the case for complex, fast-paced, or unfamiliar content. Helping students to manage the essential processing for such content can reduce the memory demands and free memory capacity for generative processing. The three current principles for managing essential processing are the segmenting, pretraining, and modality principles. For the multimedia learning materials used in this study, the modality principle was followed by the use of audiovisual learning materials with titles and labels with no additional text; segmenting was possible as learners could use pause and stop, as well as features for re-watching sections of the instructional videos (although most learners did not use these features, presenting a limitation discussed in chapter five); and pre-training was not used because of time and resource constraints.

Segmenting principle.

The segmenting principle allows learners to control the flow of information as smaller units of chunks of information (Mayer & Moreno, 2010). This control is important for learning content that has many interacting and parts, especially if those parts must be held in memory at the same time. Segmenting can allow learners to build up mental representations in small units and add to those units at a pace commensurate with their processing speed. This commensurate speed avoids cognitive overload with material being presented faster than learners can construct mental representations to integrate the new material.

Three studies have reported five experiments on segmenting. Mayer and Chandler first reported a segmenting effect in 2001 with multimedia learning materials on lightning formation, reporting an effect size of 1.13. In 2003, Mayer, Dow, and Mayer reported effect sizes of 0.82 and 0.98 for two experiments on segmenting with materials on how electric motors function. Moreno (2007) found smaller but still significant effect sizes of 0.39 and 0.61 for learning materials on teaching principles. The median effect size for studies on segmenting was 0.82.

Table 6: Summary of Segmenting Principle Experimental Results

Content	Effect size	Source	Experiment
Lightning	1.13	Mayer & Chandler, 2001	2
Electric motor	0.82	Mayer, Dow, & Mayer, 2003	2a
Electric motor	0.98	Mayer, Dow, & Mayer, 2003	2b
Teaching principles	0.39	Moreno, 2007	1
Teaching principles	0.61	Moreno, 2007	2
Median	0.82		

Pretraining principle.

Pretraining occurs when a learner is provided with opportunities to learn the main components of a system to be studied later in order to reduce the number of tasks that must be done when viewing the primary multimedia learning materials (Mayer & Moreno, 2010). An example of this is pretraining a learner on the main components of a braking system, such as the piston, before the learner views a multimedia presentation on how all the components of the system work together to brake a vehicle.

Five studies have reported nine experiments that demonstrate the pre-training principle. In the context of electrical engineering learning materials, effect sizes of 1.21 and 1.15 were reported (Pollack, Chandler, & Sweller, 2002). For learning materials with brakes, pre-training yielded effect sizes of 0.79 and 0.92 in two experiments (Mayer, Mathias, & Wetzell, 2002). An effect size of 1.00 was produced in an experiment on pre-training on how tire pumps work (Mayer, Mathias, & Wetzell, 2002). Effect sizes of 0.57 and 0.85 were reported for experiments with a geology simulation game (Mayer, Mautone, & Prothero, 2002). Bos, Terlouw, and

Pilot performed an experiment with a 2x2 design testing the effects of pre-training and pre-tests, which can be considered a type of small-scale pre-training (2009). This experiment was done with a larger-scale lesson that covered content from physics, chemistry, and computer science with some material from other content areas. The group that received pre-training but no pre-test had an effect size of 2.48 relative to the control group and the group received both pre-training and a pre-test had an effect size of 3.37. Musallam (2010) performed a pre-training experiment with learning materials on chemical equilibrium and reported an effect size of 0.94. The median effect size for all these studies is 0.97.

Table 7: Summary of Pretraining Principle Experimental Results

Content	Effect size	Source	Experiment
Electrical engineering	1.21	Pollack et al., 2002	1
Electrical engineering	1.15	Pollack et al., 2002	3
Brakes	0.79	Mayer, Mathias, & Wetzell, 2002	1
Brakes	0.92	Mayer, Mathias, & Wetzell, 2002	2
Tire pump	1.00	Mayer, Mathias, & Wetzell, 2002	3
Geology simulation game	0.57	Mayer, Mautone, & Prothero, 2002	2
Geology simulation game	0.85	Mayer, Mautone, & Prothero, 2002	3
Chemistry, physics, computer science	2.48	Bos, Terlouw, & Pilot, 2009	1a
Chemistry, physics, computer science	3.37	Bos, Terlouw, & Pilot, 2009	1b
Chemical equilibrium	0.94	Musallam, 2010	1
Median	0.97		

Modality principle.

The modality principle is the most heavily researched principle of multimedia design (Mayer & Moreno, 2010). Simply put, the principle is that narration and animation are better than narration and on-screen text with respect to learning outcomes. Presenting text along with animation or images causes learners to split their visual attention between the two, similar to the design problem when the spatial contiguity principle is not followed. Presenting the text as audio shifts the cognitive demands for that material from the visual to the auditory channel and reduces cognitive load, allowing more capacity for other mental processing activities.

Ginns (2005) reviewed 43 experiments on the modality principle and found a mean weighted effect size of $d=0.72$ favoring the modality principle. In addition to finding general support across the studies for the modality principle, Ginns found evidence that the strength of the effect of modality was strongly moderated by the complexity of the learning task, and also strongly moderated by whether the materials were self-paced (following the segmenting principle) or system-paced.

Principles for fostering generative processing.

While techniques to reduce extraneous processing and to manage essential processing focus on reducing the cognitive demands of learning and freeing up cognitive capacity, techniques that foster generative processing focus on improving and/or increasing mental effort put into integrating new learning with prior knowledge (Moreno & Mayer, 2010). Generative processing can be accomplished through the multimedia, guided activity, feedback, reflection, and personalization principles. Personalization is also a social agency effect and is described in more

detail with other social agency effects later in this chapter in place of a detailed description in this section. The principles from this group that were used in the multimedia learning materials used in this study include the multimedia principle which was followed by the use of narration and images in the learning materials and the personalization (you) effect which was studied in conjunction with personification (s/he) as primary variables in this dissertation study. Because the multimedia learning materials were instructional videos, the guided activity, feedback, and reflection principles were not applicable.

Multimedia principle.

The multimedia principle states that students learn better from a combination of text and images or narration and images than from text, narration, or images alone (Moreno & Mayer, 2010). The theoretical basis for this effect is that the different coding systems for pictures and words, known as dual coding theory (Paivio, 1986), reinforce each other. When learners are presented with the different information from the two systems, the learners then have to organize and connect the information from the two systems. This organization and connection builds a mental representation and begins the process of integrating the mental representation with prior knowledge, an act of generative processing. Building these connections should improve students' ability to transfer the knowledge to novel situations and measurements have indicated that students learning with multimedia materials perform better on such transfer tests.

Guided activity principle.

When students work with multimedia learning materials that require students to engage in problem solving with a pedagogical agent, the guided activity principle

is at work (Moreno & Mayer, 2010). A pedagogical agent provides guidance and feedback to the learner, so that the activity is interactive. Five common types of interactivity provided in guided activity materials are manipulating, dialoguing, controlling, searching, and navigating the learning materials (Moreno & Mayer, 2010). The most common interactivities are manipulating, where students can set conditions or parameters to run an experiment or test a hypothesis, and dialoguing, where students receive feedback on answers or ask questions and receive answers (Moreno & Mayer, 2010).

The guided activity principle has been tested in two settings, one the *Design-A-Plant* environment (Moreno, Mayer, Spires, & Lester, 2001) and the other a mathematical environment for learning the addition and subtraction of integers (Moreno & Duran, 2004). The botany environment was used with middle school students (experiment 1) and college students (experiments 2 and 3), with the third experiment including a visible on-screen pedagogical agent not used in experiments 1 and 2. Effect sizes for these three experiments were 0.95, 1.20, and 0.70, respectively. For the study on mathematics instruction with elementary school students, the effect size was 0.50 and the mean for all the experiments was 0.83.

Table 8: Summary of Guided Activity Principle Experimental Results

Content	Effect size	Source	Experiment
Botany	0.95	Moreno et al., 2001	1
Botany	1.20	Moreno et al., 2001	2
Botany	0.70	Moreno et al., 2001	3
Math	0.50	Moreno & Duran, 2004	1
Median	0.83		

Feedback principle.

When students learn with explanatory feedback that includes verbal explanations relating to the procedure and a visual metaphor, score better on tests of transfer (applications of knowledge, such as problem-solving) than students who only receive feedback about the correctness of their answers (Moreno & Mayer, 2010). This improvement is referred to as the feedback principle. Explanatory feedback is thought to encourage essential and generative processing because it provides guidance for the selection and integration of the presented information. Explanatory feedback may also work by increasing learners' motivation or otherwise influencing learners to improve learning outcomes

Three papers have reported five experiments in on the guided feedback principle. Moreno and Mayer reported an explanatory feedback experiment with mathematical learning material in 1999 with an effect size of 0.47. Then in 2004, Moreno reported two experiments with plant learning materials with effect sizes of 1.16 and 1.58. Moreno and Mayer (2005) reported an additional experiment in explanatory feedback with plant learning materials with an effect size of 1.31. The median effect size from these experiments is 1.24.

Table 9: Summary of Feedback Principle Experimental Results

Content	Effect size	Source	Experiment
Math	0.47	Moreno & Mayer, 1999	1
Botany	1.16	Moreno, 2004	1
Botany	1.58	Moreno, 2004	2
Botany	1.31	Moreno & Mayer, 2005	1
Median	1.24		

Reflection principle.

The reflection principle is at work when learning materials cause students to reflect on correct answers to generate more meaningful learning (Moreno & Mayer, 2010). The reflection can be produced through elaborate interrogation, where students answer why questions about the learning materials, and through self-explanations, where students explain methods that lead to correct answers or compare their work to a worked-out example. Reflection must require deep processing with respect to the learning materials and not merely superficial processing. Without deep processing, reflection fails to foster generative processing and the integration of new learning with prior knowledge.

Three papers reported four experiments that provide evidence in support of the reflection principle. Moreno and Mayer reported two experiments in 2005 with plant learning materials that produced effect sizes of 0.98 and 0.80. Moreno and Valdez (2005) reported another experiment with plant learning materials that yielded an effect size of 0.71. Moreno, Reisslein, and Ozogul (2009) reported an effect size of 0.74 for an experiment with electrical engineering learning materials. The median effect size for these experiments was 0.77

Table 10: Summary of Reflection Principle Experimental Results

Content	Effect size	Source	Experiment
Botany	0.98	Moreno & Mayer, 2005	2
Botany	0.80	Moreno & Mayer, 2005	3
Botany	0.71	Moreno & Valdez, 2005	3
Electrical engineering	0.74	Moreno, Reisslein, & Ozogul, 2009	1

Median 0.77

Personalization principle.

While the other principles for fostering generative processing seem to directly require learners to engage in answering questions, or integrating material, or reflecting on processes, the personalization principle is thought to act through a more subtle method. The personalization principle states that learning materials should be written in conversational style that addresses the learner directly as “you” instead of in a traditional, formal style that is in the so-called “objective third person.” The traditional style is most obvious in phrases like “one would now do this.” Personalization would directly address the learner using the phrasing “you would now do this.” Personalization is thought to act by stimulating a social response in learners that leads to an increase generative processing. The stimulus, response, and outcomes are explained through Social Agency Theory. This principle is the foundation for the proposed study and is mentioned here to place it in context with the other principles for fostering generative processing, but is described in more detail in the following sections along with Social Agency Theory and social agency effects.

Summary and principles applied in the current study.

CTML provides a framework for understanding how learners engage with and learn using multimedia learning materials (Mayer, 2009). CTML also provides a theory for understanding and explaining principles for designing better learning materials and for understanding and explaining the effects that changes in learning materials have on learning outcomes (Mayer & Moreno, 2010; Moreno & Mayer, 2010). These include explaining how extraneous processing can be reduced through

better instructional design, how essential processing can be managed through materials that help students deal with the cognitive requirements of learning materials, and how generative processing can be promoted through direct and indirect means that improve the integration of new learning with prior knowledge.

The specific principles which have been followed in the construction of the learning materials for this study, and which have been verified by content experts using the video content expert rating sheet in Appendix D, are the coherence principle (removing unnecessary content), redundancy principle (removing on-screen text that is redundant with narration), signaling principle (using verbal and visual cues to draw attention and highlight organization), temporal contiguity principle (timing images and narration to occur simultaneously), spatial contiguity principle (spacing labels and images for close proximity), segmenting principle (allowing learners control over pacing with pause, stop, and re-view capabilities), multimedia principle (using images and narration or text instead of only images, narration or text), and modality principle (using narration and images instead of narration and on-screen text). The personalization (you) principle and personification (s/he) have been included in certain versions of the learning materials for this study as independent variables and other principles for designing multimedia learning materials were not followed because they did not apply to instructional videos. The segmenting principle is treated with additional detail in the discussion in chapter five because while students could pause, stop, and re-watch sections of the video, the students did not actually do so and the principle was not fully utilized in the implementation of the learning materials. As many CTML principles were followed as possible, under the

assumption that it makes pedagogical sense to use as many as possible, but there are no empirical studies that confirm this assumption that using as many principles as possible is helpful for learning.

Related to CTML, the above principles for the design of multimedia learning materials, and generative processing is Social Agency Theory, which further explains the Personalization Principle and related effects (Mayer, 2009).

Social Agency Theory

Even when students study alone, there is an implied conversation occurring with an absent author through the words as text or narration (Mayer, 2009).

Face-to-face conversations between humans are social events and the implied conversation when studying alone may be experienced as social events. If these implied conversations are experienced as social events, then they could also be subject to the social cues that influence normal conversations. Those social cues may affect the amount of effort learners expend to make sense of the learning materials. The possible social cues can include speaker intonation and word choice in implied conversations, even when the teacher-author is absent. Social cues and the associated increase in learner effort provide a way to improve learning outcomes by increasing the learner's cognitive effort (Mayer, 2009). This presents a contrast to other methods of improving learning outcomes by decreasing cognitive effort by decreasing extraneous processing and managing essential processing.

The case for social agency effects posits that presenting social cues cause learners to make greater effort in learning (Mayer, 2009). Learners who make greater

effort are more likely to construct mental representations (essential processing) and to integrate those mental representations with prior knowledge (generative processing).

With computer-based materials, research has shown that humans readily accept computers as social partners and interact with them accordingly. Humans are known to interact with social partners to work to make sense of the partner in the interaction. Thus humans may be affected by the social cues present in a social interaction when they are working with computers.

Social Agency combines this research to construct a model where learners accept computers delivering multimedia learning materials as social partners engaged in an implied conversation (Mayer, 2009). When the implied conversation contains social cues, learners may follow the role of the listener in the Cooperation Principle and work to make sense of the information being presented. As part of the implicit agreement of the Cooperation Principle, learners expect the speaker (through text or narration) to work to be accurate, informative, concise, and relevant. When social cues are missing, a social response and the Cooperation Principle may not be triggered and learners may make less effort to learn the information. When learners receive social cues and make greater effort, learning outcomes are improved.

Social Agency Effects

The social agency effects that have been studied to date are the voice effect (Mayer, 2009), the image effect (Mayer, 2009), the politeness effect (Wang et al., 2008), and the personalization effect (Mayer, 2005b).

Voice and Image Effects.

The first social agency effect is the Voice Effect (Mayer, 2009), where narration with a native English speaker using a standard accent and friendly tone leads to greater learning outcomes than narration using a high quality speech synthesizer does. Three Voice Effect experiments have produced results favoring the human voice over a machine voice with effect sizes from 0.69 to 0.79

A second social agency effect is the image effect, which involves the presence or absence of the speaker's image on the computer screen (Mayer 2009). Five experiments evaluated this effect. Four studies used an animated character and one study used a non-animated human character. The effect sizes for the five studies were inconsistent and weak, ranging from -0.50 to 0.35, with a median value of 0.22. These values show that including a speaker's image in multimedia learning materials does not necessarily increase learning (Mayer 2009).

Politeness Effect.

A third social agency effect is the Politeness Effect (Wang et al, 2008; McLaren, DeLeeuw & Mayer 2011). Two studies that used online tutors to help students develop problem-solving skills examined the effect of using polite language. The polite language included first and second person personal pronouns (specifically we and you), polite vocabulary (such as please), and polite phrasing (such as "Let's do this" and "Why don't we..."). This language indicated connections between the learner and the subject matter and was intended to induce a social response to increase learners' efforts. Politeness is thought to work by increasing learners' senses of autonomy (also called minimizing negative face) and approval (also called

increasing positive face). The effect size for the first experiment conducted on the politeness effect was 0.71. For the second study the effect size was 0.78 on an immediate test and 0.51 on a delayed test for learners with low prior knowledge of the subject material. (Learners with high prior knowledge showed a reverse effect with an effect size of -0.47 immediately after the treatment and an effect size of -0.13 on a later test.)

Personalization Effect

The Personalization Effect in multimedia learning materials describes the change in language from formal third person language to personalized language that includes informal first and second person pronouns (we and you) that directly addresses the learner (Mayer, 2009). An example of a traditional formal script is:

In very rainy environments plant leaves have to be flexible so that they are not damaged by the rainfall. What really matters for the rain is the choice between thick leaves and thin leaves.

When the same script is personalized, the result is:

This is a very rainy environment and the leaves of your plant have to be flexible so they're not damaged by the rainfall. What really matters for the rain is your choice between thick leaves and thin leaves.

The Personalization Effect has been shown to improve learning outcomes consistently with transfer (applications and problem-solving) items and sometimes with retention items (recall of information; Mayer, 2005). The personalization effect has been studied in three content areas: lightning generation (Moreno & Mayer, 2000),

plant physiology (Moreno & Mayer, 2000 & 2004), and lung physiology (Mayer, 2004).

Multimedia presentations of lightning formation.

In a lesson on lightning, a formal neutral third person style script was compared to a personalized script (Moreno & Mayer, 2000). The lesson explained cloud formation, cold and warm air drafts within clouds, charge accumulation, leaders, and lightning strikes. Most of these phenomena can be experienced through vision or touch. The personalization script included visual references and described sensory experiences of warmth and cold. The personalized version of the multimedia presentation resulted in statistically significant improvements in transfer and retention with effect sizes of 1.00 and 0.15, respectively for the first experiment. A second experiment on lightning used on-screen text in place of narration and produced effect sizes favoring personalization for transfer (1.60) and retention again (0.20). The experiments on lightning and personalization are summarized in the table below.

Table 11: Summary of Personalization Effect Experiments for a Multimedia Presentation Lesson on Lightning Formation

Experiment 1	Narrated Language type: Traditional v. personalized	Transfer (1.00) Retention (0.15)
Experiment 2	On-screen text Language type: Traditional v. personalized	Transfer (1.60) Retention (0.20)

(Moreno & Mayer, 2000)

Educational game studies with plant physiology.

In the materials on botany and plant characteristics, personalization was used in an educational computer game where students designed plants for alien worlds

(Moreno & Mayer, 2000 & 2004). In the game, students had to match plant characteristics with environments where those characteristics would allow the plant to thrive. The researchers measured possible indicators of social agency (motivation, interest, understanding, and friendliness) along with learning effects in retention and transfer items and the perceived difficulty of the material. The social agency effects and the perceived difficulty were combined into one variable called program rating and were not reported separately from each other. Three versions of the game were tested with, and without, personalization. Experiment three in the 2000 study (numbering continued from experiments one and two on lightning formation) included rhetorical thought-provoking questions while experiment four replaced the audio narration with on-screen text and experiment five used the audio narration but removed the rhetorical thought-provoking questions. For all three experiments, the effect sizes for transfer items were large: 1.55, 1.58, and 1.11, respectively. The effect sizes for retention were not as large, but still sizeable with values of 0.83, 0.57, and 0.56 for the three experiments.

Moreno and Mayer (2000) included a variable called program rating that consisted of a combination of eight items that measured participants' motivation, interest, and understanding as well as the perceived difficulty of the material and the friendliness of the program. Responses to each item were chosen from ten point scales. Motivation was measured using the item: "If you had a chance to use this program with new environmental conditions, how eager would you be to do so?" Interest levels were assessed using the two items "How interesting is this material?" and "How entertaining is this material?" Understanding was assessed using the two

items "How much does this material help you understand the relation between plant design and the environment?" and "How helpful is this material for learning about plant design?" Perceived difficulty of the material was assessed using the two items "How difficult was the material?" and "How much effort is required to learn the material?" Friendliness of the program was assessed using the item "How friendly was the computer that you interacted with?" and a ten-point friendliness scale that ranged from not very friendly (1) to very friendly (10).

The eight items above that measured participants' motivation, interest, and understanding as well as the perceived difficulty of the material and the friendliness of the program were combined into one variable called program rating. Results for the program ratings were not statistically significant, but trended in the direction favoring personalization and the result for experiment 4 approached statistical significance. Mayer has continued to attempt to measure several of the components of program rating in subsequent studies to elucidate how social agency theory operates. Ongoing measures have included interest, difficulty, and friendliness. The understanding item about helpfulness has also been used in later studies, but it has been used as an indicator of perceived helpfulness of the program and not to indicate learner understanding.

Table 12: Summary of Personalization Effect Experiments for an Instructional Game on Plant Physiology

Experiment 3:	Narrated Language type: Traditional v. personalized with rhetorical questions	Transfer (1.55) Retention (0.83) Program rating* (ns), • $t(37) = 0.69$ • $p = 0.50$
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		<ul style="list-style-type: none"> • $es=0.21$
Experiment 4:	On-screen text Language type: Traditional v. personalized with rhetorical questions	Transfer (1.58) Retention (0.57) Program rating* (ns), <ul style="list-style-type: none"> • $t(40) = 1.98$ • $p = 0.06$ • $es=0.70$
Experiment 5:	Narrated Language type: Traditional v. personalized without rhetorical questions	Transfer (0.89) Retention (0.56) Program rating* (ns), <ul style="list-style-type: none"> • $t(41) = 1.11$ • $p = 0.77$ • $es=0.33$

(Moreno & Mayer, 2000)

* Rating combines eight separate items that measured motivation, interest, understanding, difficulty, and friendliness.

Virtual reality setting: interactivity level and personalization.

In a 2004 study, the computer version of the plant physiology game was compared to a virtual reality version of the game and social agency measures were again included in the experiments (Moreno & Mayer, 2004). The experiment in the 2004 study compared four treatments with two independent variables in a two-by-two design. The independent variables were language with two levels, traditional and personalized, and immersion level with two levels, low (desktop computer environment) and high (virtual reality environment). The four treatments were computer-based with traditional language, computer-based with personalized language, virtual reality with traditional language, and virtual reality with personalized language.

Learning outcomes for the 2004 study were mixed. Transfer measures revealed a main effect between the personalized and traditional language with an effect size of 1.64, but no significant difference between high and low immersion

environments. Retention measures revealed a main effect between the personalized and traditional language with an effect size of 0.77. Retention measures also revealed a main effect favoring the low immersion environment over the high immersion environment with an effect size of 0.73. While the transfer effect sizes were larger than those for retention, the retention effect sizes in this study were larger than in previous studies.

Social agency measures for the 2004 plant physiology study were also mixed. Friendliness ratings revealed a main effect between the personalized and traditional language with an effect size of 0.50, but no significant interaction between language type and immersion level. The differences for friendliness ratings were not significant between the high and low immersion levels. Helpfulness ratings revealed a main effect between the personalized and traditional language with an effect size of 0.47, but no significant interaction between language type and immersion level. The differences for helpfulness ratings were not significant between the high and low immersion levels.

Cognitive load was indirectly measured in the 2004 plant physiology study using difficulty ratings. Difficulty ratings revealed a main effect between the personalized and traditional language with an effect size of 0.67, but no significant interaction between language type and immersion level. Difficulty ratings also revealed no significant difference for a main effect between high and low immersion levels.

The following table outlines the results of the 2004 Moreno and Mayer study. Since the study involved a two-by-two design, for each dependent variable there were

two main effects evaluated, namely language type (traditional versus personalized) and immersion level (low/computer version versus high/virtual reality version). The table is organized to show the results of the two main effects for each dependent variable. There were no statistically significant interactions between language type and immersion level for any of the dependent variables so there is no information on interaction effects included in the table.

Table 13: Summary of Personalization Effect Experiments for an Instructional Game on Plant Physiology, Varying Level of Immersion and Type of Language Used

Dependent Variable	Independent Variable	F value (df between, within)	P-value	Effect size
Transfer	Language type	$F(1, 44) = 37.36$	0.0001	1.64
	Immersion level	Not significant and reverse of expected direction		
Retention	Language type	$F(1, 44) = 11.14$	0.002	0.77
	Immersion level	$F(1, 44) = 5.22$	0.05	0.73
Friendliness	Language type	$F(1, 44) = 4.05$	0.05	0.50
	Immersion level	Not significant		
Helpfulness	Language type	$F(1, 44) = 4.01$	0.05	0.47
	Immersion level	Not significant		
Difficulty	Language type	$F(1, 44) = 4.22$	0.05	0.67
	Immersion level	Not significant		
Physical presence	Language type	$F(1, 44) = 8.41$	0.006	0.85
	Immersion level	$F(1, 44) = 4.04$		

(Moreno & Mayer, 2004)

Multimedia presentations on lung physiology.

In a study on lung function, students viewed a narrated animation on lung physiology (Mayer, 2004). The control version of the animation used formal language while the personalized version included twelve minor changes where the word “the” was replaced with the word “your.” Learners who viewed the personalized version scored significantly higher on transfer tests (effect size of 0.65) but not significantly higher on retention tests. Second and third experiments used the same narrated animations, but added measures of learner interest and perceived difficulty. Experiment two added a measure of facial expressions to gauge interest while experiment three added learner interest and difficulty ratings.

Tests of transfer in experiments two and three were statistically significant, with effect sizes of 1.07 and 0.37 for experiments two and three respectively. Differences in retention outcomes were not statistically significant. These outcomes parallel those of experiment one.

Attempts to measure social priming in the lung physiology study included facial expression and interest rating measures. Facial expressions were found to be an insensitive measure of interest in experiment two. In experiment three, interest and difficulty were measured using student ratings. Statistically significant differences were not detected, but the differences measured trended in the hypothesized directions, with the personalized treatment group rating interest higher and difficulty lower than the control group. Mayer proposed that either the interest measurement item was defective or the hypothesis that personalization increases interest was incorrect. Sense of personal relevance of the material was described as another possible avenue for social priming but was not measured in the experiments. Larger samples with greater power or the use of different instruments for measuring these variables might result in statistically significant results for interest and difficulty. The results of the experiments are tabulated as follows.

Table 14: Summary of Personalization Effect Experiments for a Multimedia
Presentation Lesson on Lung Physiology

Experiment 1:	Script type: Traditional v. personalized	Transfer (0.65) Retention (ns)
Experiment 2:	Script type: Traditional v. personalized	Transfer (1.07) Retention (ns) Facial expression (ns)
Experiment 3:	Script type: Traditional v. personalized	Transfer (0.37) Retention (ns) Interest (ns) Difficulty (ns)

(Mayer et al., 2004)

Limitations of personalization studies.

The three major studies on the personalization effect used multimedia instructional videos and computer or virtual-reality games to elicit the effect. The length of time for the videos was approximately 140 seconds (Moreno & Mayer, 2000) or 60 seconds (Mayer et al., 2004), much shorter than most classroom lectures or explanations. For the games, the time spent playing the games was 14-16 minutes (Moreno & Mayer, 2004) or 24-28 minutes (Moreno & Mayer, 2000), which is much closer to the length of classroom lectures and explanations. There have not been studies on personalization with longer length instructional videos that more closely match the duration of classroom lectures and explanations. As well, longer instructional videos would allow for testing the effect with more complex learning materials that more closely resemble the complex subject matter covered in classical lectures, as in college science courses.

Additionally, the studies on personalization have all been done with college age students who choose to participate in the study. There have been no studies of

the effects of personalization on high school age students, who would be expected to have significant cognitive and maturity differences compared to college students. Also, there have been no studies with students studying mandatory subjects they have not chosen to study. Students who have not chosen to participate or study a certain subject could exhibit weaker, stronger, or equal responses to the personalization effect; there are no experiments or data to determine which response is the case.

Summary.

Despite these limitations, the three major studies on the personalization effect consistently show medium to large effect sizes for increases in transfer outcomes using personalized language compared to traditional language. Retention outcomes are more mixed, ranging from statistically insignificant to statistically significant with medium effect sizes. Measures of social agency and perceived difficulty are similarly mixed across studies, ranging from statistically not significant to medium effect sizes. Additional measures of retention and social agency may allow for a closer examination of how social agency works and develop further details of Social Agency Theory. As well, measures of the effect of personalization and other social agency effects with longer length instructional videos may inform the importance of the effect in practical situations as compared to laboratory situations.

Summary

The Cognitive Theory of Multimedia Learning explains how students learn from multimedia materials by combining dual auditory and visual processing channels with the concept of limited memory capacity for students to engage in

extraneous, essential, and generative processing. Extraneous processing is undesirable and can be reduced by following the:

- Coherence principle and removing extraneous elements from learning materials,
- Redundancy principle and removing redundant on-screen text from learning materials,
- Signaling principle and providing clues to learners about the organization of learning materials and which elements to focus attention on during learning,
- Temporal contiguity principle and combining images and videos with referenced narration to occur simultaneously, and
- Spatial contiguity principle and reducing the distance between related elements in images and videos in learning materials.

The amount of essential processing, the generation of mental representations of the learning material, can be reduced by helping learners to manage the essential material by following the:

- Segmenting principle and presenting material in smaller amounts to prevent cognitive overload, including allowing learners to control the pace of presentations,
- Pretraining principle and presenting learners with information on the elements of learning materials ahead of presenting the primary and more complex learning materials, and
- Modality principle, where learners are presented with information through multiple learning and sensory modes, such as auditory and visual modes.

Generative processing is desirable for learning as it involves integrating new learning with prior knowledge and can be fostered by the following the:

- Multimedia principle, where learning materials are presented using the visual and auditory channels, instead of only one of the channels, to promote the mental representation of the learning materials,
- Personalization principle, where informal language that addresses the learner directly is used to increase learners' cognitive effort,
- Guided activity principle, where learners are required to engage in problem solving with guidance and feedback from a pedagogical agent,
- Feedback principle, where learners receive explanatory feedback along with corrective feedback, and
- Reflection principle, where interrogation and self-explanations help learners reflect and integrate new learning with prior knowledge.

Social Agency Theory explains personalization and related effects that operate by eliciting a social response from learners by presenting them with social cues in the learning materials. Social agency effects include the

- Voice Effect that favors the human voice over synthetic voices,
- Image Effect that indicates that the visual image of a speaker in multimedia learning materials does not necessarily improve learning,
- Politeness effect that language that promotes autonomy and approval improves learning, and
- Personalization effect that informal language that addresses the learner directly increases learning.

The Personalization Effect has been studied in the areas of lightning formation, plant physiology, and lung physiology using multimedia presentations, educational games, and virtual reality settings. These studies have investigated retention learning outcomes with mixed results and transfer learning outcomes with consistently significant results and substantial effect sizes. Attempts to measure the effects of social cues and the ways in which social responses may occur have generated mixed results.

Multimedia Chemistry Instruction

While textbooks can be considered multimedia instructional materials because they include text and pictures, this study is focused on multimedia instructional materials that take advantage of auditory and visual processing by using audiovisual multimedia instruction. This review of multimedia chemistry instruction begins with early instructional movies, then describes a shift to addressing learning chemistry in the context of three levels of chemical representation and chemistry-specific design principles, and then addresses how this redirection has taken chemistry multimedia instructional materials and studies away from CTML and the design principles associated with CTML.

The early years: Instructional chemistry movies

The earliest examples of this kind of instructional materials are instructional films, beginning in 1957 with instructional chemistry movies made in Oregon for closed circuit television systems (Pekdag & Le Marechal, 2010; Slabaugh & Hatch, 1958). Chemistry instructional movies developed and early studies showed that students learned equally well, if not better, than from textbooks and lectures (Pekdag

& Le Marechal, 2010; Slabaugh & Hatch, 1958; Duffy & Walsh, 1969; Enger et al., 1978). Benefits of using instructional videos in chemistry included reduced costs compared to lectures, unimpeded views of chemical demonstrations in movies (as opposed to impeded views in classrooms), the use of close-up shots for improved observation, time lapse videography to reveal the details of fast reactions, the ability to present procedures that otherwise could not be shown in a classroom for safety or cost reasons, and the ability to control presentations through rewind, fast forward, and other options (Pekdag & Le Marechal, 2010; Nienhowe & Nash, 1971; Pantaleo, 1975; Fortman & Battino, 1992).

Uses of the instructional movies included the introduction of material, lecture replacement, presentation of lab equipment and methods, generating learner interest and motivation, teacher training, and testing and evaluation (Pekdag & Marechal, 2010; Nienhowe & Nash, 1971; Pantaleo, 1975; Fortman & Battino, 1992). One problem cited with the instructional videos was the inability to ask questions of the presenter (Pekdag & Marechal, 2010). This inability to interact with the materials was partially improved with the advent of laserdiscs and computers (Pekdag & Marechal, 2010; Russell, 1984).

Levels of representation and chemistry-specific design principles

Following the early chemistry instructional movies, researchers in the 1990's identified three levels of representation in chemistry for multimedia chemistry instructional materials to address: the macroscopic level that is directly observed through sight and the other senses; the submicroscopic level of molecules, ions, atoms, and other particles that cannot be seen; and the symbolic level of chemical and

mathematical symbols and equations that chemists use to describe and explain the macroscopic and submicroscopic levels (Bowen, 1998; Gabel & Bunce, 1994). Expert chemists use symbolic level language to explain physically observed macroscopic level phenomena through the behavior of submicroscopic level molecules, atoms, and particles (Kozma, 2003). Students, however, do not explain macroscopic level phenomena at the molecular level (Abraham, Grybowski, Renner & Marek, 1992; Abraham, Williamson & Westbrook, 1994; Haider & Abraham, 1991). Furthermore, expert chemists use underlying principles through symbolic level models and equations to connect information while students and novices use surface features, such as experimental facts and graph types to connect information (Kozma, 2003). In addition to not explaining chemistry at the molecular level and focusing on surface features, students frequently use chemical and mathematical symbols without understanding them (Friedel & Maloney, 1992; Yaroch, 1985).

In response to these findings, instructional designers were advised that instruction should form links between the three levels of understanding chemistry (Gabel, 1993; Haider & Abraham, 1991; Johnstone, 1993; and Lee, 1999). Computer-based technology provides powerful means for understanding chemistry as it provides an opportunity to represent the three levels of chemistry at the same time (Kozma, 1991; Russel et al., 1997). This presentation enables deeper coding and more expert-like mental models of the particulate nature of matter (Williamson & Abraham, 1995). Kozma (2003) specifically recommended three design principles, namely (1) to use at least one representation that explicitly connects the learning material to directly observed physical phenomena; (2), to require students to use

multiple linked representations while they are engaged in laboratory activities; and (3) to require students to collaborate as they use the representations to confirm and explain the results of laboratory investigations.

Research and development of multimedia chemistry instruction

Following the chemistry-specific recommendations for multimedia chemistry instructional materials, there have been several studies into multimedia chemistry instruction using instructional software, videos, and animations. None of these studies have focused on the model of the atom or the electronic structure of atoms. Most of the studies have focused on the levels of chemical representations and helping students connect two or three of these levels, but the majority have ignored the general design principles from CTML for multimedia learning materials. The contributions for teaching chemical representations from these studies have not been applied or extended to other areas of instruction.

The first group of multimedia chemistry instructional materials described here focused on helping students connect submicroscopic level atoms and molecules to symbolic level chemical formulas. Appling and Frank (1999) developed molecular visualization software as part of the Discover Chemistry supplemental materials for a chemistry textbook and focused on improving students ability to connect the sub-microscopic level of atoms with chemical symbols, but did not connect to the third level of macroscopic effects that students can observe directly. Littlejohn et al. (2002) reported on the use of a web-based organic chemistry tutorial program for students to use in studying carbohydrate chemistry. The program allowed students to draw and manipulate structural formulas to help students connect chemical formulas

and molecular structure, after which the program assessed those formulas and provided programmed feedback to the students.

Other chemistry multimedia learning materials focused on helping students connect macroscopic level of chemistry from laboratory experiments with the submicroscopic level. One example is when Velázquez-Marcano et al. (2004) used a combination of video-recorded chemical demonstrations and computer-generated animations to teach about three experiments dealing with effusion and diffusion of gases and vapors. Kozma and Russell (2005) reviewed two multimedia chemistry instructional programs of this type, ChemSense and ChemDiscovery. ChemSense allowed students to create and analyze representations of experiments using drawing tools, animation, graphing, and textual materials while ChemDiscovery (previously known as ChemQuest) made use of interactive web pages and included eight projects in its curriculum.

More complex chemistry multimedia learning materials included the macroscopic level of chemistry from laboratory experiments as well as the submicroscopic and symbolic levels. Nick et al. (2003) reported on the development of one such set of materials called CHEMnet, a free online learning suite, comprised of an online learning system, simulations, videos, animations, and three dimensional structural drawings. D'Amato et al. (2007) combined traditional lectures, multimedia instruction, and a laboratory activity in their study on how the addition of multimedia instruction would affect student learning about fuel-cell concepts in an introductory college chemistry course.

Many of the above chemistry multimedia instructional studies used materials that violated design principles of CTML. For example, the CHEMnet learning suite screenshots provided in the study paper (Nick et al., 2003) and the screenshots in the D'Amato et al. (2007) study appear to violate either the redundancy principle (Mayer, 2001) by providing a large amount of on-screen text that would repeat auditory information, or the multimedia effect (Mayer, 2001) by presenting information as text that could be provided as narration.

Multimedia chemistry instruction and CTML

In addition to the above chemistry multimedia instructional materials that focused on helping students connect the three levels of chemistry (macroscopic, submicroscopic, and symbolic), there have been a small number of studies with multimedia chemistry instructional materials that are more directly related to principles associated with CTML.

Evans (2008) compared student learning outcomes for students studying chemical stoichiometry using multimedia review materials against students using a text-based study guide, finding a small but significant advantage for students with the multimedia review materials. This study is essentially an extension to chemistry of the multimedia principle (that using images and text or narration is better than only using text).

Suprasorn (2008) reported on the comparison of an animation with narration to an animation with text for students studying organic chemistry extractions using the Organic Extraction Simulation multimedia instructional materials. The narration group had higher scores than the text group. This study is essentially an extension to

chemistry of the modality principle (that using narration and visual presentation is better than visual only).

In spite of the direct connections of the Evans (2008) and Suprasorn (2008) studies to the multimedia and modality principles of CTML, screenshots from both studies indicate that they, like the CHEMnet and D'Amato studies, appear to violate either the redundancy principle (Mayer, 2001) by providing a large amount of on-screen text that would repeat auditory information, or the multimedia effect (Mayer, 2001) by presenting information as text that could be provided as narration.

Gregorius et al. (2010a & b) created instructional multimedia animations that were used to compare the effects of instructional animations to textbook reading and discussion for elementary school students and to compare the effects of instructional animations to lecture and discussion for high school students. For both groups of students, the students learning with the multimedia materials (animations) received higher scores, and further analysis confirmed that the design effects were stronger for low-knowledge learners than for high-knowledge learners. These studies were again essentially extensions of the modality principle to chemistry.

In contrast to these studies which applied known principles to multimedia chemistry instructional materials, Bos, Terlouw & Pilot (2009) studied the effect of including or omitting a pre-test on post-treatment scores for students studying with multimedia instructional materials on a variety of scientific topics from several sciences. The chemistry topics included in the instruction were atomic theory, molecular structure, and some organic, especially organic chemistry with biological

connections. The study found the use of a pre-test increased student scores, which may parallel the use of pre-training or other forms of additional instruction.

Also fairly different from the other multimedia chemistry instructional studies, Tolentino et al (2009) reported a study using a multimedia instruction that did not use personal computer screens as the focus for student attention. The study used what the authors describe as mixed-reality learning called the SMALLab, or Situated Multimedia Arts Learning Laboratory. The laboratory consisted of a projection onto the floor in the center of the classroom and a motion sensor located above the projection. The projection showed a virtual experiment with water and reactive chemicals in the middle of the projection and various chemicals located on the border. The virtual lab was configured so that students were able to mimic a titration experiment, adding acid or base from the projection border. The middle area showed acid and base molecules interacting when students added different chemicals. The set-up required full-body movement and encouraged students to work together to choose chemicals to add and to interpret the outcomes. Working with the SMALLab resulted in large learning gains for the students. Unfortunately, all the study groups used the SMALLab after teaching a traditional unit in the chemistry classes, so there were no control or comparison groups. The authors state that the learning improvements with the treatment represented learning beyond what was accomplished in the classroom with traditional methods, but there could also be learning gains for students who study the same material a second time even with traditional methods. More research directly comparing this new multimedia tool to traditional teaching and other multimedia tools is needed.

While some of the multimedia chemistry instructional studies have touched on extending CTML principles to chemistry, and sometimes not necessarily with the intention of doing so (Evans, 2008; Suprasorn, 2008), they have also not always attempted to implement known CTML design principles. The study in this dissertation investigates not only multimedia chemistry instruction following CTML design principles, but also the extension of those principles by applying personalization (you) to chemistry and by testing a new principle, personification (s/he), in chemistry instruction.

Gender and stereotype threat in science and mathematics

A growing body of research is showing that differences in students performance in many areas, including mathematics and science, can be attributed to the presence of gender stereotypes (Schmader, 2002). These studies have shown that triggering explicit or implicit awareness of an individual's membership in a stereotyped group (such as racial/ethnic groups, gender groups, and others) can diminish that individual's performance in various areas, including achievement tests.

Stereotypes and gender

Stereotype is typically used to describe the initial labeling and presuppositions that are made about someone based on their membership in a particular social group, such as a race, gender, ability, sexual orientation, ethnicity, or religion (Conway-Klaasen, 2010). Stereotyping can be positive or negative, but at best, it is limiting and restrictive, such as when males are praised for aggressive behavior and females are praised for being neat (Conway-Klaasen, 2010). In addition to granting praise for

stereotypical behaviors, praise can be withheld when females express stereotypically male traits or behaviors (Conway-Klaasen, 2010).

Stereotyping can feed into parents' evaluation of their children's abilities, such as when Bussey & Bandura (1999) found that while their children had equivalent performance in achievement tests, parents believed their male children had greater natural ability in analytical and mathematical tasks. Without parental support, females may choose not to pursue math and science (Conway-Klaasen, 2010).

Stereotype threat

Steele & Aronson (1995) first identified and studied stereotype threat in the context of African American students and their academic performance. They defined stereotype threat as the risk of confirming a negative stereotype about one's particular demographic group. Studies have investigated stereotype threat with respect to racial groups, gender, and socioeconomic status on performance in sports, academics, and memory tasks (Brown & Lee, 2005; Croizet & Duteuil, 2004; Hess, Auman, Colcombe, & Rahhal, 2003; Keller, 2002; Kiefer & Sekaquaptewa, 2006; McFarland, Lev-Arey, & Ziegert, 2003; Ployhart, Ziegert, & McFarland, 2003; Spencer et al., 1999; Stone, Sjomeling, Lynch, & Darley, 1999; Wicherts, Dolan, & Hessen, 2005).

Smith (2004) proposed the Stereotyped Task Engagement Process (STEP) model to explain how stereotype threat induction works. Smith proposed that individual characteristics along with an environment or situation that triggered mental awareness of one's membership in a stereotyped group could generate positive or negative self-regulation in the individual. Negative effects could include feelings of anxiety that may then lead to diminished performance (Smith, 2004). The individual

does not have to believe the negative stereotypes that are activated in the environment for them to generate stereotype threat and diminish performance.

First among the individual characteristics which have been identified and studied that affect stereotype threat is domain identity, the degree to which success in that domain is important to the individual (Smith & Johnson, 2006). The more the subject domain matters to the individual, the stronger the effect of stereotype threat has been found to be (Keller, 2007; Conway-Klaasen, 2010; Aronson et al., 1998; C. M. Steele, 1998). For example, a student who more strongly identifies as a scientist would be more susceptible to stereotype threat. This characteristic may be important with students taking required courses that the students have not chosen to take. Students in these classes may have low levels of domain identity.

The second individual characteristic identified is the strength of the group identification, the degree to which an individual feels connected to and part of a specific social group (Schmader, 2002). A third individual characteristic of note is stigma consciousness, the degree to which the individual is aware of the negative stereotypes about her/his group (Brown & Pinel, 2003). Fourth is self-efficacy, the degree to which the individual believes that s/he is capable of performing well (Hoyt, 2005). Fifth is locus of control, the degree to which an individual believes that s/he can control events that affect her/him (Cadinu et al., 2006). Most recently, the degree to which the mother (but not the father) embraces gender stereotypes has been shown to affect the strength of stereotype threat (Tomasetto, Alparone, & Cadinu, 2011). Also, the type of school attended by females has been shown to affect stereotype

threat, with females who attend all-female schools showing lower levels of stereotype threat than who attend coed schools (Picho & Stephens, 2012).

In addition to the individual characteristics above, the difficulty of the test questions has been shown to affect the degree of stereotype threat (Keller, 2007). With easier test questions, stereotype threat has not been detected (Keller, 2007; Conway-Klaasen, 2010). Stereotype threat is not activated by easy test questions, but is activated by harder test questions. Male students may perceive harder test questions as simply being harder questions, while female students may perceive harder test questions as possible evidence for negative stereotypes about females.

Stereotype threat can be activated explicitly or implicitly, or attempts can be made to neutralize it (Conway-Klaasen, 2010). Explicit activation of stereotype threat has been conducted in studies where subjects were told directly that females had performed worse than males on an achievement test or other measure (Conway-Klaasen, 2010; Keller, 2007). Implicit activation is, as the name implies, more subtle (Kiefer & Sekaquaptewa, 2006, 2007; Smith & Johnson, 2006; Smith & White, 2002). Implicit activation has been conducted by making the individual a minority in the testing setting (Inzlicht & Ben-Zeev, 2000, 2003). Taking an intelligence test has been found to be sufficient to implicitly activate stereotype threat for minority students, and taking a mathematics test can implicitly activate stereotype threat for female students (Kiefer & Sekaquaptewa, 2006, 2007; Kunda, Davies, Adams, & Spencer, 2002; Levi, Stroessner, & Dweck, 1998; Smith & White, 2002). Similar to implicit activation, priming, i.e., asking the individual for demographic information (race or gender) prior to testing, can generate stereotype threat as well (Steele, 1995).

Stricker and Ward (2004) of the Educational Testing Service (ETS) reported contrary results to Steele, but reexamination of the ETS data by Danaher and Crandall (2008) found significant differences corresponding to whether minority subjects were asked for race and gender data before or after testing.

Contrary to stereotype threat activation, some studies have sought to neutralize stereotype threat by informing subjects that minority groups have done as well as majority groups on tests (Keller, 2007; Campbell & Collaer, 2009). Women's performance in the neutralization group was significantly better, both statistically and practically, compared to the explicit and implicit stereotype threat groups in both studies (Keller, 2007; Campbell & Collaer, 2009).

Summary

Given that studies have shown how stereotype threat diminishes the performance of under-represented groups in areas like mathematics and science, it is important to avoid or neutralize it (Conway-Klaasen, 2010). Also, in research it is important to determine whether new educational materials and approaches trigger stereotype threat in order to best serve students who are members of under-represented and stereotyped groups (Conway-Klaasen, 2010).

Summary

The preceding sections have described the known effects with multimedia learning materials that lead to improved learning by decreasing extraneous processing, managing essential processing, and promoting generative processing (Mayer, 2009). The materials developed for use in this study will be designed to decrease extraneous processing and manage essential processing by following design principles and

effects described in this chapter and to evaluate an existing tool, personalization (you), along with a proposed tool, personification (s/he), to determine if the tools improve learning outcomes for students, either alone or together (by personalizing and personifying the treatment to include both you and s/he).

The tools of personalization (you) and personification (s/he) will be tested with multimedia chemistry learning materials. Some previously developed multimedia chemistry learning materials have confirmed that multimedia effects and design principles known from studies in other disciplines also apply to chemistry (Appling and Peake, 2004; Littlejohn et al., 2002; D'Amato et al., 2007; Evans, 2008). Other previously developed multimedia chemistry learning materials have not always followed known design principals, such as the multimedia principle and the redundancy effect (Nick et al., 2003; D'Amato et al., 2007; Evans, 2008). The proposed study evaluated a known tool, personalization (you), which has not previously been investigated with chemistry instruction, and a new tool, personification (s/he), while also making sure that the multimedia materials followed known design principles for effective multimedia instruction.

In addition to testing the potential improvements in learning using these tools, it is important to recognize the potential for activation of stereotype threat for female students when gender-specific pronouns are used in the personification (s/he) experimental treatments. Stereotype threat occurs when the learner is reminded of her membership in a group that is stereotyped as being deficient in the content or performance area (Aronson & Steele, 1995). This reminder then can lead the learner

to become anxious and diminish the learner's performance on measured tasks (Smith, 2004).

Given the possibility of stereotype threat and its possible influence on the performance of females studying chemistry, design effects in multimedia chemistry learning materials need to be examined for the presence of stereotype threat. Multimedia learning materials have so far been neutral with respect to stereotype threat in that no possible activation of stereotype threat has been studied, even though there could possibly be an implicit activation of stereotype threat (Steele, 1998). With the addition of a personification effect, it is possible that the use of gender-specific pronouns could prime students for stereotype threat effects.

This research study examined the effects of personalization (you) and personification (s/he) in chemistry multimedia learning materials. The effects studied included potential learning improvements through retention (simple recall) and transfer (application and problem-solving) test items, for personalization (you) alone, personification (s/he) alone, and for the combination of both personalization (you) and personification (s/he) together in one treatment. To examine for possible gender interactions and stereotype threat, there were two versions of the personification (s/he) treatment, with male pronouns in one treatment version and female pronouns in the other. There were also two versions of the combination treatment, with male pronouns in one treatment version and female pronouns in the other.

Chapter 3

Methodology

This study investigated the effects of using personified (s/he) and personalized (you) language in multimedia learning materials on the electronic structure of atoms with high school students as the subjects. A possible interaction between the personified (s/he) language and the gender of the subject was examined. In this section the experimental research design is outlined and described. Following a restatement of the research questions, a description of the design, sampling procedures, human subject considerations and data analysis methods are discussed. This section concludes with a description of the treatment, and study limitations, followed by a summary of the overall methodology.

Research Questions

The research questions are:

1. What are the effects on student learning (retention/recall and transfer/problem-solving and application) when learning materials are changed from traditional language to language that is personalized (you), personified (s/he), or both?
2. To what extent do the six treatment conditions create stereotype threat conditions for participants? For example, do females in the personified male (he) treatment group have lower scores than males in the same treatment group?
3. To what extent do females or males in any of the treatment conditions perform better than in the other conditions? For example, do females in the

personification female (she) treatment group perform better than females in the personification male (he) treatment group?

Research Design

This study was designed as a quasi-experimental investigation with a sample of students from co-ed, all-male, and all-female religious high schools in northern California. Subjects were randomly assigned to one of six treatments: (1) traditional formal language without personalization (you) or personification (s/he), (2) personalized (you) language only, (3) masculine personified (he) language only, (4) feminine personified (she) language only, (5) language that is both personalized (you) and uses male personification (he), and (6) language that is both personalized (you) and uses female personification (she). Figure 3 shows the treatment groups and their relationship to each other.

Figure 3: Treatment Groups with Personalization and Personification Factors

		Personified (s/he)		
		No	Yes, male	Yes, female
Personalized (you)	No	Traditional formal language	Male personified (he) language only	Female personified (she) language only
	Yes	Personalized (you) language only	Personalized (you) and male personified (he)	Personalized (you) and female personified (she)

Because changes in cognitive load must be measured in the context of prior knowledge (Sweller et al., 1998), a pre-test was administered to subjects to determine their knowledge level of the subject before the treatment.

When participants entered the testing and treatment area, each participant was directed to a computer workstation and directed to one of six websites. Each participant was randomly assigned to one of the six websites by drawing papers with website URLs from an envelope. The websites guided the participants through the pre-test, the treatment (each student receives one of the six variations of the multimedia presentation), and then through the post-test and survey questions. Since participants viewed the exact same visual material, there was no chance of cross-contamination by participants seeing what was on other computer screens in the testing area. To prevent cross-contamination by participants hearing the audio content of other treatments, headphones were distributed and used to isolate the audio content each participant receives.

The dependent variables to be measured were knowledge of electronic structure of atoms, at the retention (recall) level and at the deeper transfer (application and problem-solving) level.

Sampling Procedure

Participants were recruited through classes at the participating schools. Science teachers with students who had not yet studied the electronic structure of atoms were approached and asked for their classes to spend one class period participating in the study. Students in the classes where teachers agreed to participate were then be approached and asked to participate in the study. Parental consent was also sought, and a consent form with an opt-out option was distributed physically in class and electronically via email. Thus, the participants in this study were a volunteer sample of 329 high school students who had not completed high school

chemistry at the four participating religious schools in an urban Northern California city. The all-female high school has an enrollment of approximately 200 while the all-male high schools have enrollments of approximately 160 and 570. The co-ed high school has an enrollment of approximately 1200 students. From these schools, 329 students participated in total.

Protection of Human Subjects

Approval for this study was obtained from the University of San Francisco's Internal Review Board for Protection of Human Subjects (IRBPHS). A permission letter (Appendix A) was obtained from each participating academic institution, and informed consent was obtained from each participant (Appendix B). Given the age of the participants, parental consent for research participation was also requested, but not always obtained since passive (opt-out) consent was allowed by IRBPHS. For students who chose not to participate (or whose parents opted them out of the study), they were allowed to answer the pre-test questions (without submitting their answers), to watch one of the video treatments, and to answer the post-treatment test and survey questions (again without submitting their answers). Along with the informed consent letter, a cover letter describing the study, the instruments, and explaining the confidentiality terms of the study was distributed to each participant (Appendix C).

Instrumentation

The instrumentation for this study included a mixture of common subject area specific questions on chemistry for retention (recall) and transfer (application and problem-solving). The pre-test contained only retention items while the post-test contained retention and transfer items. The researcher wrote preliminary versions of

the pre-test (Appendix A) and post-test (Appendix B) and pilot tested them with 30 students in his chemistry and honors chemistry classes at one of the all-male high schools participating in the study. For these students, the researcher was both the administrator of the pilot test and the classroom teacher. Results from the pilot test were used to remove items that reduced reliability from the pre-test and post-test and to shorten the length of the tests without compromising reliability. Removal of items was done in order to shorten the test lengths to minimize learner fatigue. Items were removed by calculating values for reliability using Cronbach's alpha with the item removed. Items were not removed if the item removal would have reduced the reliability of the test. The reduced test items were then submitted to other chemistry teachers with a Content Expert Rating Sheet (Appendix C) for evaluation of the items and the tests were aligned and modified based on the content experts' recommendations.

Pre-test development, reliability, and item reduction analysis.

For the pre-test, the researcher initially wrote 29 questions, with 25 based on electronic structure intended to test retention (recall) of knowledge about the electronic structure of atoms and 4 questions asking students directly about their knowledge of chemistry and previous course history, similar to those in previous personalization (you) studies (Moreno & Mayer, 2000 & 2004; Mayer, 2004). The 25 initial pre-test items based on electronic structure required participants to:

- (1) match electron configurations with various elements,
- (2) identify the shell and subshell information from electron configurations,

- (3) answer questions about the number of electrons in various shells and subshells of atoms,
- (4) answer questions about ionic charges, and
- (5) answer questions about relative atomic sizes.

The initial version of the pre-test was pilot tested and the results analyzed for reliability and descriptive statistics using SPSS.

For the full 29-item initial pre-test (Appendix A), Cronbach's alpha was determined to be 0.571. The individual items were analyzed to determine what Cronbach's alpha would be if they were removed in order to increase the reliability of the pre-test and to shorten the length of the pre-test by reducing the number of test questions. Removing item 9 increased Cronbach's alpha to 0.637. The removal of item 9 increased Cronbach's alpha more than removal of any other item would and so item 9 was removed. Re-analysis of the remaining 28 items indicated that removing item 3 increased Cronbach's alpha to 0.684 (again increasing Cronbach's alpha more than any other item) and item 3 was removed. Re-analysis of the remaining 27 items indicated that removing item 10 increased Cronbach's alpha to 0.712 and item 10 was removed. This process was repeated until items 9, 3, 10, 6, 1, 2, 8, 18, 13, 12, 23, 16, 17, 21, 26, 27, and 4 had been removed, leaving 12 items with a Cronbach's alpha of 0.825. At this point, analysis of possible item removal indicated that the removal of any further items also reduced the reliability as indicated by Cronbach's alpha so no further items were removed. Table 15 details the order of removal of 17 items from the initial pre-test and the corresponding changes in Cronbach's alpha as the items were removed.

Table 15: Pre-Test Item Reduction Process Details

Order of Removal	Item Number	Cronbach's Alpha
	None	0.571
1	9	0.637
2	3	0.684
3	10	0.712
4	6	0.729
5	1	0.745
6	2	0.761
7	8	0.775
8	18	0.787
9	13	0.794
10	12	0.800
11	23	0.804
12	16	0.807
13	17	0.810
14	21	0.814
15	26	0.818
16	27	0.823
17	4	0.825

The scores students obtained for these 12 items were analyzed for a floor effect. For the 12 items retained in the pre-test after item reduction analysis, the theoretical maximum was 12 and the theoretical minimum was 0. The actual scores from the pre-test had a minimum of zero and a maximum score of 10 with a mean of 2.54 and a standard deviation of 2.53. The theoretical floor for the 12 items can be calculated according to the formula published by Roberts (1978), where choices is the number of choices for the item and items represents the number of items with that number of choices:

$$floor = \frac{1}{choices - 1} \times items$$

Since the 12 items retained in the pre-test did not have the same number of choices, the floor is obtained by calculating the floor value for each group of items and summing those values. For the two 5-choice items, the calculated floor is 0.5. For the four 3-choice items, the calculated floor is 2. For the short answer items, the calculated floor is zero. The floor for the 12 items together is 2.5, which is only 0.04 away from the obtained mean of 2.54. This situation indicates that the subjects in the pilot test had no prior knowledge of electronic structure. In the following analysis in this section of the same items for the post-test on retention, no such floor effect is observed.

Post-test development, reliability, and item reduction analysis for retention.

For the post-test, the researcher initially wrote 53 questions, of which the first 25 items were the same as those on the initial pre-test and were intended to test retention (recall) of knowledge about the electronic structure of atoms. The 25 retention items were numbered (5 through 29) to match the numbering of the same items in the pre-test. The remaining 9 questions (numbered 30 through 38) were designed to test transfer (application and problem-solving) of knowledge of the electronic structure of atoms. The initial version of the post-test (Appendix B) was pilot tested and the results analyzed for reliability using SPSS. Reliability and item reduction analysis for the 25 retention items was carried out separately from the reliability and item reduction analysis for the 9 transfer items.

For the full 25 retention items in the initial post-test (Appendix B), Cronbach's alpha was determined to be 0.907. The individual items were analyzed to

determine what Cronbach's alpha would be if they were removed in order to increase the reliability of the post-test retention items and to shorten the length of the post-test by reducing the number of test questions. Removing item 20 increased Cronbach's alpha to 0.910 and item 20 was removed. Re-analysis of the remaining 28 items indicated that removing item 17 increased Cronbach's alpha to 0.912 and item 17 was removed. Re-analysis of the remaining 27 items indicated that removing item 29 increased Cronbach's alpha to 0.913 and item 29 was removed. This process was repeated until items 20, 17, 29, 18, 12, and 13 had been removed, leaving 19 items with a Cronbach's alpha of 0.914. At this point, analysis of possible item removal indicated that the removal of any further items also reduced the reliability as indicated by Cronbach's alpha so no further items were removed. Table 16 details the order of removal of 6 items from the initial post-test retention scale and the corresponding changes in Cronbach's alpha as the items were removed.

Table 16: Post-Test Retention Item Reduction Process Details

Order of Removal	Item Number	Cronbach's Alpha
	None	0.907
1	20	0.910
2	17	0.912
3	29	0.913
4	18	0.914
5	12	0.914
6	13	0.914

For the 19 items retained in the retention test, the theoretical maximum is 19 and the theoretical minimum is 0. The actual scores from the post-test ranged from a minimum of 0 to a maximum score of 19 with a mean of 9.61 and a standard deviation of 5.65. The theoretical ceiling of the test would be 75% of the items

answered correctly based on Roberts' (1978) guidelines, which for the 19 retention items would be 14.25, well above the obtained mean of 9.61. The scores are also well above the floor of the test since the mean score is approximately 50% correct for the 19 items.

Post-test development, reliability, and item reduction analysis for transfer.

The 9 initial post-test transfer items required participants to apply the concepts of electronic structure and to solve problems as opposed to recalling facts and simple information about electronic structure, as the retention items did. More specifically, the transfer items required participants to:

1) Explain what is wrong with the following electron configurations.

One problem with an invalid shell (0s)

One problem with non-available subshell (1p)

One problem with too many electrons in a subshell ($2s^3$)

One problem with a valid configuration

2) How are shells and subshells related to each other in atoms?

3) What happens when there are too many electrons to fit inside a subshell?

4) What happens to the electron configuration of an atom with 8 electrons if the s subshell can hold 4 electrons instead of 2?

For the full 9 transfer items in the initial post-test (Appendix B), Cronbach's alpha was determined to be 0.745. The individual items were analyzed to determine what Cronbach's alpha would be if they were removed in order to increase the reliability of the post-test transfer items and to shorten the length of the post-test by reducing the number of test questions. Removing item 35 increased Cronbach's

alpha to 0.759 and item 35 was removed. Re-analysis of the remaining 8 items indicated that removing item 37 increased Cronbach's alpha to 0.777 and item 37 was removed. At this point, analysis of possible item removal indicated that the removal of any further items also reduced the reliability as indicated by Cronbach's alpha so no further items were removed. Table 17 details the order of removal of 2 items from the initial post-test transfer scale and the corresponding changes in Cronbach's alpha as the items were removed.

Table 17: Post-Test Transfer Item Reduction Process Details

Order of Removal	Item Number	Cronbach's Alpha
	None	0.745
1	35	0.759
2	37	0.777

For the 7 items retained in the transfer test, the theoretical maximum is 7 and the theoretical minimum is 0. The actual transfer scores from the post-test had a minimum of zero and a maximum score of 7 with a mean of 3.54 and a standard deviation of 2.49, indicating no floor or ceiling effect for these items.

Validity

The reduced list of pre-test and post-test items were checked for validity by content matter experts using the *Content Expert Rating Sheet* (Prion, 2012). The content matter experts were experienced high school chemistry teachers (each with over 10 years of experience teaching chemistry), one of whom has also completed a doctoral dissertation on CTML focusing on pre-training and its effects (Musallam, 2010). There were twenty-seven distinct items remaining for the pre-test and post-test (some items are used on both tests) for validity checking. The content matter

experts were experienced chemistry teachers (more than five years experience each), one of whom also has completed a doctoral dissertation in multimedia chemistry educational materials.

For the 12 items reviewed from the reduced items in the pre-test, two items were identified by the content experts as measures of transfer (applications and problem-solving) while the other ten were identified as retention, or simple recall items. Removal of these two items (numbers 24 and 25 on the initial pre-test) lowered the reliability from 0.825 to 0.804. Since these items are being used in the pre-test as a measure of prior content knowledge and not specifically as measures of retention, they will be retained for use in the final pre-test.

Three items from the original pre-test were flagged as possibly being too basic, but the improvement of reliability with these items included indicates that the items were not too basic for the subjects in the pilot test. As well, the low scores overall on the pre-test indicate that the items were unlikely to be too basic.

Another recommendation made by the content experts included rewording four items, which was done for the final version of the pre-test. Two other items were flagged as being potentially unclear with the recommendation to change the items to multiple-choice format instead of short answer and these changes were made. The last recommendation was to change one of the incorrect answer choices on a multiple choice item and this change was also made.

For the retention section of the post-test, ten of the items were identical to items in the pre-test. Recommendations for changes on those items were made in both the pre-test and the post-test. For the other retention items in the post-test, there

were no recommendations from the reviewers to change the wording, format, or distractors.

There were, however, recommendations from the reviewers that four items were transfer items instead of retention items. Two of the items were the same ones identified in the pre-test as being misclassified, items 24 and 25. The other two items that were identified (numbers 26 and 27) were very similar to items 24 and 25. Adding these four items to the other transfer items reduces Cronbach's alpha for the transfer items from 0.777 to 0.610. Removing these four items from the retention scale reduces Cronbach's alpha for retention from 0.914 to 0.911. These items were removed from the final post-test since expert reviewers indicated that they were not retention items and removing them did not reduce the reliability (Cronbach's alpha) to an unacceptable level. These items were not retained for use as transfer items since the inclusion of the items would have severely reduced the reliability of the transfer scale.

For the transfer items, there was one recommendation to change the wording of an item and this was done for the final post-test. Another recommendation was to make sure that an item was placed early in the post-test. The version in the pilot test did not have the item placed early, but it still contributed significantly to the reliability for the transfer items. The item was moved, but the data did not clearly confirm that the reviewer's intuition was correct. Another transfer item was flagged by one reviewer as being too obvious, but the contribution of the item to the transfer score reliability indicated that the item was not too easy and that it contributed significantly to the scale reliability, so the item was retained. The difficulty in

categorizing and identifying retention and transfer items indicates that there may be some utility in performing regression, reliability analysis, and dimension reduction (factor analysis) for the full data set to support the distinction between retention and transfer.

Procedures

The researcher administered the treatments, pre-tests, and post-tests. In all cases, the subjects are not students the researcher teaches in his regular classes. The purpose of the study was outlined in the materials distributed for informed participant and parental consent. The materials (cover letter, informed consent form, and a parental consent form) were distributed to eligible students at the participating schools. Students who chose to participate were randomly assigned to one of the six testing conditions when they entered the computer lab using random website URLs drawn from a bag, representing each of the testing conditions. Participating students received a copy of the informed consent form and a copy of the Research Subject's Bill of Rights.

Treatments and measures for the study were conducted in one session. At the beginning of the session, participants were assigned to one of the study conditions and used a computer with the online pre-test, instructional chemistry video, and the online post-test. Once participants were seated at a computer station, they completed the pre-test items to measure prior knowledge. Then participants viewed one of the six video presentation treatments. Immediately after viewing the video, each participant completed retention and transfer questions on the post-test and reported

her/his gender at the very end to ensure that recording gender did not prime students for stereotype threat.

The total time each study participant spent was approximately 40 minutes, with a 5 minute introduction, 5 minutes for the pre-test, 20 minutes for the video treatment, and 10-15 minutes for the post-test. Timing was observed rather than enforced. Time for the pre-test and post-test were not restricted, but most participants spent 5 minutes on the pre-test and 10-15 minutes on the post-test. The six treatment videos were all approximately 21 minutes in length (mean length was 20:58 with a standard deviation of 68 seconds) and most participants watched the videos directly from beginning to end without pausing, stopping, skipping, or reviewing any portions of the videos.

Data collection occurred over five different days at the different school locations. Most of the data collection was done in computer labs located in separate rooms or libraries. For two schools, data collection also included laptop computers used in a multi-purpose room. The dates of data collection were February 16 and 17; and March 5, 7, 8, 15, and 20, 2012.

Treatments

The six different treatments used during data collection were multimedia instructional videos that corresponded to the absence of both personalization (you) and/or personification (s/he). Students with individual personal computers and headphones viewed the videos independently, with the video lengths ranging from 19 minutes 38 seconds to 22 minutes 36 seconds, with a mean length of 20 minutes 58 seconds and a standard deviation of 68 seconds. The videos used 82 images with an

audio script soundtrack. The six versions of the videos used the same images and scripts that differed only in the presence or absence of personalization (you) and personification (s/he).

The subject matter for the multimedia chemistry instructional videos is the electronic structure of atoms, including shells, subshells, and electron configurations, along with periodic properties related to electronic structure, including patterns in atomic size and ionic charges. The subject matter was chosen for its complexity and difficulty (Colburn, 2009; Breuer, 2002; Millikan, 1982). The periodic table was chosen as a learning tool and tracking device for teaching about electron configurations (Strong, 1986) and mirrors common usage among chemists who refer to sections of the periodic table as s, p, d, and f blocks, referring to the s, p, d, and f subshells where valence (i.e. outermost) electrons are located in atoms. 82 images were developed in PowerPoint using the periodic table and standard images of electron shells and subshells for use in the treatment multimedia videos. These images were designed to follow certain applicable CTML design principles: coherence principle (removing unnecessary content), redundancy principle (removing on-screen text that is redundant with narration), signaling principle (using visual cues to draw attention and highlight organization), spatial contiguity principle (spacing labels and images for close proximity), multimedia principle (using images and narration or text instead of only images, narration or text), and modality principle (using narration and images instead of narration and on-screen text).

To accompany the 82 images that constituted the video element of the multimedia chemistry instructional videos, different audio soundtracks were prepared

that corresponded to the six treatment conditions. The images used in all six versions of the treatment videos were identical. First, the audio soundtracks were written as scripts for recording. Audio recording was done using a handheld recording microphone. The audio files were then imported into a laptop computer and edited using Audacity software to remove stutters and other audio problems.

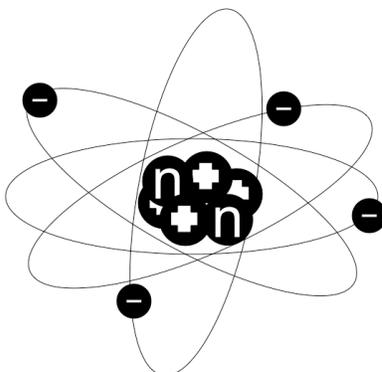
Different versions of the audio scripts and soundtracks were developed to correspond to the three study variables: presence or absence of personalization (you), presence or absence of personification (s/he), and gender of personification (she versus he). These three study variables were isolated and combined into six treatments that varied only in the audio script and soundtrack language: (1) traditional formal language without personalization (you) or personification (s/he), (2) personalized (you) language only, (3) masculine personified (he) language only, (4) feminine personified (she) language only, (5) language that is both personalized (you) and uses male personification (he), and (6) language that is both personalized (you) and uses female personification (she).

For example, the script for the traditional formal language without personalization (you) or personification (s/he) for the second slide uses the following language:

Atoms are the smallest unit of matter that can still be an element. Particles that are smaller than atoms are no longer elements, but are called elementary particles or subatomic particles. Atoms are therefore also the smallest units of the elements. Atoms consist of electrons and a nucleus with neutrons and protons, but the study of chemistry is primarily concerned with the electrons.

This script accompanies the image in Figure 4 below.

Figure 4: Slide Two for All Six Treatments



In contrast to this example is the script for the same section that is personalized (you) only:

“Atoms are the smallest unit of matter that you can still consider an element. You can’t call particles that are smaller than atoms elements, but instead you call them elementary particles or subatomic particles. Atoms are therefore also the smallest units of the elements. If you could see an atom, you would see that it consists of electrons and a nucleus with neutrons and protons.

When you study chemistry, you are primarily concerned with the electrons.”

For the masculine personified (he) language only the script is:

Atoms are the smallest unit of matter that can still be an element. A particle that is smaller than an atom is no longer an element, but he is called an elementary particle or a subatomic particle. An atom is therefore also the smallest unit of an element and he consists of electrons and a nucleus with neutrons and protons. The study of chemistry is primarily concerned with his electrons.

For the feminine personified (she) language only the script is:

Atoms are the smallest unit of matter that can still be considered an element. A particle that is smaller than an atom is no longer elements, but she is called an elementary particle or a subatomic particle. An atom is therefore also the smallest unit of an element and she consists of electrons and a nucleus with neutrons and protons. The study of chemistry is primarily concerned with her electrons.

For the script with language that is both personalized (you) and uses male personification (he) the corresponding section is:

Atoms are the smallest unit of matter that you can still consider an element. You can't call a particle that is smaller than an atom an element, but instead you would call him an elementary particle or a subatomic particle. Atoms are therefore also the smallest units of the elements. If you could see an atom, you would see that he consists of electrons and a nucleus with neutrons and protons. When you study chemistry, you are primarily concerned with his electrons.

Finally, the last version that uses language that is both personalized (you) and female personified (she) has this wording:

Atoms are the smallest unit of matter that you can still consider an element. You can't call a particle that is smaller than an atom an element, but instead you would call her an elementary particle or a subatomic particle. Atoms are therefore also the smallest units of the elements. If you could see an atom, you would see that she consists of electrons and a nucleus with neutrons and

protons. When you study chemistry, you are primarily concerned with her electrons.

The complete scripts for all six versions are included in Appendix G.

The audio scripts and soundtracks were prepared to test the effects of two CTML design principles, personalization (you) and personification (s/he). In addition to testing these two principles, the audio scripts and soundtracks were prepared following these general CTML design principles: coherence principle (removing unnecessary content), signaling principle (using verbal cues to draw attention and highlight organization), temporal contiguity principle (timing images and narration to occur simultaneously), multimedia principle (using images and narration or text instead of only images, narration or text), and modality principle (using narration and images instead of narration and on-screen text).

After preparing the one set of images and the six different soundtracks, the image files were imported into KeyNote and integrated with the audio soundtracks. The integrated images and audio files were exported from KeyNote as six different QuickTime formatted video files and saved as the six distinct multimedia chemistry instructional treatment videos. The integration of the images and soundtracks was done following these CTML design principles: coherence principle (removing unnecessary content), redundancy principle (removing on-screen text that is redundant with narration), signaling principle (using verbal and visual cues to draw attention and highlight organization), temporal contiguity principle (timing images and narration to occur simultaneously), spatial contiguity principle (spacing labels and images for close proximity), segmenting principle (allowing learners control over

spacing with pause, stop, and re-view capabilities), multimedia principle (using images and narration or text instead of only images, narration or text), and modality principle (using narration and images instead of narration and on-screen text).

The treatment video for the combination personalized (you) and female personified (she) was chosen for the reviewers to evaluate and that video file was sent to reviewers along with the Video Content Expert Rating Sheet (Appendix D). The Video Content Expert Rating Sheet contains each slide and the accompanying narration for each slide. The ratings ask experts to evaluate the images and narration based on the design principles and learning effects associated with the Cognitive Theory of Multimedia Learning (CTML) from Chapter 2. Specifically, reviewers evaluated for materials that would cause extraneous processing, that contain redundant text (redundancy principle), that present issues with timing (temporal contiguity principle), that have poor placement of images (spatial contiguity principle), and that have insufficient verbal indicators, such as sentences that preview the section, phrases that serve as headings, and intonations on linking words and phrases (signaling principle). The reviewers found that the video was congruent with the design principles and recommended no changes to the images and/or audio content.

Data Analysis

Prior Knowledge Assessment.

Because intrinsic cognitive load is a function of learner prior knowledge, all participants completed the pre-treatment test to determine their prior knowledge level. Student scores for prior knowledge were used to separate the scores for high-prior

knowledge students. Participants with high prior knowledge showed little to no improvement in learning outcomes from using the video presentation treatments and including these participants with low-prior knowledge participants could obscure positive effects for the low-prior knowledge participants.

Research Question 1.

To answer research question 1, the retention and transfer scores were compared amongst the six groups in two ways. The results of retention and transfer items were compared separately from each other. The six groups were compared using a one-way ANOVA for retention and again for transfer.

Research Question 2.

Research question 2 was addressed by comparing the scores for female and male participants in each of the six treatment groups using independent samples t-tests. Lower scores for females in a group would have possibly indicated a stereotype threat condition. Patterns in differences between the groups would have been examined for consistency if a stereotype threat condition had been indicated. For example, if females in the personification male (he) group had significantly lower scores than males, that situation would be compared to the combination personalization (you) and personification male (he) group to see if stereotype threat were present in that group as well.

Research Question 3.

Research question 3 was addressed by comparing the results across the six treatment conditions for female participants using a one-way ANOVA to determine if any of the conditions resulted in significantly different results. A parallel ANOVA

was performed for male participants across the six groups. Patterns in the mean scores for the separate genders in each of the six treatment groups were assessed to determine if females or males do better or worse when there is a gender match or mismatch between the gender of personification (s/he) language and the participant's gender.

Summary

This study investigated the effects of personalization (you) and personification (s/he) and the combination of both modifications on retention and transfer post-test items. This study also examined possible stereotype threat conditions for female participants. Prior to treatment, participants were evaluated for degree of prior knowledge of atomic electronic structure. Participants with high prior knowledge were separated in the analysis from low-prior knowledge participants.

After the prior knowledge assessment, participants in each of the six groups were exposed to a multimedia presentation with formal traditional language, personalized (you) language, personified (s/he) language (male and female), or language that is both personalized (you) and personified (s/he, male and female). Immediately after viewing the video, participants answered post-test items that required retention (simple recall of information) or transfer (application of information and problem-solving). Those results were analyzed to evaluate the relative strengths of personalization (you) and personification (s/he) compared to traditional formal language. The results were also analyzed to determine if the combination of personalization (you) and personification (s/he) is additive, redundant, multiplicative, or synergistic.

In addition to examining the results for the treatment groups, scores for the participants in each of the six treatment groups were divided by participant genders to evaluate if stereotype threat conditions existed for female students with the treatments that used personification (s/he).

For female participants in the personification female (she) treatment group and the combination personalization (you) and personification female (she) group, there was the possibility of stereotype threat if the use of female pronouns causes the female students to be primed for the threat. Comparison of the scores for female participants in these two groups to the male scores were used to evaluate if a stereotype threat condition existed for these participants.

Likewise, for female participants in the personification male (he) treatment group and the combination personalization (you) and personification male (he) group, there was also the possibility of stereotype threat if the use of male pronouns causes the female students to be primed for the threat. Comparison of the scores for female participants in these two groups to the male scores were used to evaluate if a stereotype threat condition existed for these participants.

There is also the possibility of an implicit stereotype threat in the personalization (you) and traditional language treatment groups. While the language used in the treatments for these groups is not gender specific, there is a possibility of implicit stereotype threat when female participants take the pre-test and post-test on scientific material. Female and male participants scores for these groups were used to evaluate if there is a stereotype threat condition.

Finally, there are two other possibilities that could have occurred. It was possible that females could score higher under certain treatment conditions due to social priming or identifying with the subject matter when female pronouns are used. Comparing the scores for females across the different treatment groups revealed if females score higher under these conditions. It was also possible that males may score lower under certain treatment conditions. Comparing the scores for males across the different treatment groups revealed if males score higher under any of the conditions.

CHAPTER 4

RESULTS

The purpose of this study was to investigate if personalization (you) and if personification (s/he) of learning materials increases learning outcomes compared to learning materials that use traditional neutral third person objective language. With personification (s/he), there is also a possible difference in learning outcomes if male (he) or female (she) personification is used, so the two variations of personification (she and he) were also investigated and compared. Since learners have gender, gender was included as a variable to compare possible differences when female and male students used learning materials with female and male personification (s/he).

In addition to comparing the effects of personalization (you), female personification (she), male personification (he), and traditional language, this analysis also includes a comparison of the effects on learning when personalization (you) and personification (s/he) are combined. The six treatments used in this study were:

- 1) a control with traditional formal instructional language using only neutral third person pronouns (such as it, its, they, and their),
- 2) a treatment with personalization (you) incorporating direct second person personal pronouns (such as you, your, and yours),
- 3) a treatment with personification (s/he) only incorporating male third person pronouns (such as he, him, and his),
- 4) a treatment with personification (s/he) only incorporating female third person pronouns (such as she, her, and hers),

- 5) a treatment with both personalization (you) and male personification (he), and
- 6) a treatment with both personalization (you) and female personification (she).

To make it easier to compare the separate and combined effects of personalization (you) and personification (s/he) and gender in this chapter, tables will be organized according to the study design with rows indicating whether or not personalization (you) was included in the treatment and columns indicating absence or presence and type of personification (none, she, or he) used in each treatment.

The learning outcomes were measured as retention (factual recall) and transfer (problem solving and application of knowledge). Retention was measured using a 15-item assessment and reported as percent correct and transfer was measured using a 7-item assessment and reported as percent correct. To ascertain prior knowledge level of atomic structure, electron configurations and related topics, participants were given a 12-item pre-test before administration of the treatment.

Research Question 1

What are the effects on student learning (retention/recall and transfer/problem-solving and application) when learning materials are changed from traditional language to language that is personalized (you), personified (s/he), or both?

The first research question investigated whether or not there were statistically significant differences between the six different treatment conditions with respect to retention (recall of presented information) and transfer (problem solving and application of knowledge). To control for prior knowledge, participants also completed a 12-item pre-test before viewing a video and then completing the post-test with 19 retention items and 7 transfer items.

The pre-test scores for the 329 participants ranged from 0% to 92%, with a mean of 30% and a standard deviation of 20%. Forty-four students had pre-test scores above 50% and were removed from later analysis as prior studies have indicated that these subjects do not show substantial learning improvements (confirmed in the data in this study). Since there were only 44 subjects with such high pre-test scores distributed across the six treatments, meaningful comparisons between subjects with low and high prior knowledge could not be made.

After removing the students with high prior knowledge, pre-test scores for the six treatment groups ranged from a low mean score of 21% for both the male personification (he) and the female personification (she) groups to a high group mean of 28% for the combination personalization (you) and male personification (he) group. Standard deviations for the six groups ranged from 12% for the personalization (you) only group to 17% for the traditional language group. Pre-test mean scores and standard deviations for all six groups are presented in Table 18. Table 18 is designed to reflect the study design in a three-by-two grid representing three levels of personification: none, she, and he; and two levels of personalization: none and you.

Table 18: Pre-Test Scores by Treatment Group

		Personification		
		None	She	He
Personalization	None	m= 24% s=17% n=45	m=23% s=13% n=44	m=20% s=14% n=49
	You	m=24% s=13% n=51	m=27% s=12% n=48	m=26% s=14% n=48

A one-way ANOVA test to compare the statistical equivalency of the six treatment groups yielded $F(5, 279)=1.52, p=0.18$. This result was not statistically significant, indicating that random assignment to treatment groups had yielded statistically equivalent groups.

On the post-test retention items, scores for the full 329 participants ranged from 0% to 100%, with a mean of 44% and a standard deviation of 25%. For the transfer items, scores for the 329 participants ranged from 0% to 100%, with a mean of 54% and a standard deviation of 30%. These results are presented along with the pre-test results for comparison in Table 19.

Table 19: Pre-test, Retention, and Transfer Test Descriptive Statistics

	Pre-test 12 items	Post-test Retention 15 items	Post-test Transfer 7 items
Sample size	329	329	329
Mean	30%	44%	54%
Standard deviation	20%	25%	30%
Minimum	0%	0%	0%
Maximum	92%	100%	100%

The means and standard deviations for retention items for the six different treatment groups are given in Table 20. Retention scores were quite close for all six treatment groups, with means ranging from 38% to 43% and standard deviations ranging from 21% to 26%.

Table 20: Retention Items Descriptive Statistics by Treatment Group

		Personification		
		None	She	He
Personalization	None	m=40% s=24% n=45	m=40% s=23% n=44	m=40% s=26% n=49
	You	m=38% s=23% n=51	m=43% s=25% n=48	m=38% s=21% n=48

Mean retention scores for the six different treatment groups were compared using a one-way ANOVA, which yielded $F(5, 279)=0.38, p=0.86$. This result is not statistically significant, so post-hoc tests were not performed and no effect size was calculated.

The means and standard deviations for transfer items for the six different treatment groups are given in Table 21. Transfer scores were somewhat close relative to standard deviations for all six treatment groups, with means ranging from 45% to 55% and standard deviations ranging from 27% to 32%.

Table 21: Transfer Items Descriptive Statistics by Treatment Group

		Personification		
		None	She	He
Personalization	None	m=47% s=27% n=45	m=52% s=31% n=44	m=48% s=32% n=49
	You	m=49% s=28% n=51	m=55% s=31% n=48	m=45% s=28% n=48

The mean transfer scores for the six different treatment groups were compared using a one-way ANOVA, which yielded $F(5, 58)=0.77, p=0.57$. This result is not

statistically significant, so post-hoc tests were not performed and no effect size was calculated.

Research Question 2

Do any of the six treatment conditions create stereotype threat conditions for female participants? For example, do females in the personified male (he) treatment group have lower scores than males in the same treatment group?

For this research question, scores for males and females were compared across the six treatment conditions first for the retention items and then for the transfer items. The means, standard deviations, and sample sizes for retention items for females and males in the six different treatment groups are given in Table 22. Retention scores were mostly consistent between genders and across treatments, ranging from 36% to 50%, with standard deviations ranging from 20% to 27%. The most outstanding result observed in the retention scores was the mean of 50% for female students with female personification (she) and no personalization, compared to 39% for the treatment with no personalization or personification.

Table 22: Retention Means, Standard Deviations, and Sample Sizes by Treatment

		Group and Gender		Personification		
				None	She	He
Personalization	None	Males	m=41%	m=43%	m=41%	
			s=25%	s=22%	s=25%	
			n=26	n=24	n=30	
	You	Males	m=39%	m=43%	m=41%	
			s=23%	s=22%	s=27%	
			n=29	n=28	n=27	
None	Females	m=39%	m=50%	m=39%		
		s=24%	s=23%	s=20%		
		n=19	n=20	n=19		
You	Females	m=36%	m=37%	m=41%		
		s=23%	s=23%	s=27%		
		n=22	n=20	n=21		

T tests were run to compare females and males across the six different treatments to determine if the differences in means were statistically significant. Since no statistically significant differences were observed, effect sizes were not calculated. Since this analysis included six t tests on the same data set and to reduce the probability of a false positive (Type I error), the significance level was adjusted using the Bonferroni correction by dividing the customary alpha level of .05 by six, the number of tests performed, to give a significance level of 0.008 on each individual test. None of the analyses were significant at this level, or even at the 0.05 level. One result did approach statistical significance, with the combination personalization (you) and female personification (she) giving a p value of 0.14 when comparing retention scores for males and females. This result is noteworthy because a similar result is obtained for transfer scores in the next section.

The t-test results for the combination personalized (you) and female personification (she) treatment ($t(46)=1.52, p=0.14$) came the closest to being

statistically significant and showing a strong difference between how female and male students performed. The t-test results for the five other treatments, no personalization and no personification ($t(43)=0.28, p=.78$); personification (you) only ($t(49)=0.55, p=0.59$); female personification (she) only ($t(42)=0.85, p=0.40$); male personification (he) only ($t(47)=0.58, p=0.57$); and combination personalized (you) and male personification (he) treatment ($t(46)=0.31, p=0.76$), were all far from statistically significant, indicating that female and male students performed equally under these treatment conditions.

The means, standard deviations, and sample sizes for transfer items for females and males in the six different treatment groups are given in Table 23. Transfer means ranged from 42% to 66%, with standard deviations ranging from 25% to 34%. The highest mean transfer score difference was 66% for females with the combination of personalization (you) and female personification (she) compared to 47% for males in the same treatment group.

Table 23: Transfer Items Means, Standard Deviations, and Sample Sizes by Treatment Group and Gender

		Group and Gender		Personification		
				None	She	He
Personalization	None	Males	m=48% s=29% n=26	m=57% s=31% n=24	m=50% s=34% n=30	
		Females	m=47% s=26% n=19	m=46% s=31% n=20	m=45% s=29% n=19	
	You	Males	m=46% s=29% n=29	m=47% s=33% n=28	m=42% s=27% n=27	
		Females	m=52% s=27% n=22	m=66% s=25% n=20	m=48% s=29% n=21	

T tests were run to compare females and males across the six different treatments to determine if the differences in transfer mean scores were statistically significant. Since this analysis included six t tests on the same data set and to reduce the probability of a false positive (Type I error), the significance level was adjusted using the Bonferroni correction by dividing the customary alpha level of 0.05 by six, the number of tests performed, to give a significance level of 0.008 on each individual test. Since no statistically significant differences were observed, effect sizes were not calculated. The test comparing males and females under the combination personalization (you) and female personification (she) condition gave results that approach statistical significance under the adjusted significance level with a p value of 0.04. Cohen's d was calculated for the effect size under this condition and yielded a result of 0.65, representing a medium to large effect size.

The t-test results for the combination personalized (you) and female personification (she) treatment ($t(46)=2.14, p=0.04$) came the closest to being statistically significant and showed the strongest difference between how female and male students performed. The t-test results for the five other treatments, no personalization and no personification ($t(43)=0.14, p=0.89$); personification (you) only ($t(49)=0.71, p=0.59$); female personification (she) only ($t(42)=1.22, p=0.23$); male personification (he) only ($t(47)=0.52, p=0.60$); and combination personalized (you) and male personification (he) treatment ($t(46)=0.64, p=0.52$), were all far from statistically significant, indicating that female and male students performed equally under these treatment conditions.

Research Question 3

Do females or males in any of the treatment conditions perform better than in the other conditions? For example, do females in the personification female (she) treatment group perform better than females in the personification male (he) treatment group?

Retention scores for females were mostly consistent across the six treatments, ranging from 36% to 50%, with standard deviations ranging from 20% to 27%. The traditional language group had a mean retention score of 39% and the greatest improvement was 50% for the group with female personification (she) only. Comparing only these two groups following the independent samples t-test gives a result of $t(37)=1.46, p=0.08$. While this result is not statistically significant, it does approach statistical significance. Following the Cohen's d procedure yields a medium effect size value of 0.47 for this test, indicating a practical difference for

female students between the groups, even though the test is not technically statistically significant. Comparing all six groups using ANOVA produces $F(5, 115)=1.07, p=0.38$, not a statistically significant result. Retention scores for females across the six treatments are provided in Table 24.

Table 24: Retention Scores Descriptive Statistics for Females Across Treatment

		Personification		
		None	She	He
Personalization	None	m=39% s=24% n=19	m=50% s=23% n=20	m=39% s=20% n=19
	You	m=36% s=23% n=22	m=37% s=23% n=20	m=41% s=27% n=21

Retention scores for males were almost equal across the six treatments, ranging from 39% to 43%, with standard deviations ranging from 22% to 27%. The traditional language group had a mean retention score of 41% and the differences of 2% from this group were quite small compared to the standard deviations on the retention scores. Comparing all six groups using ANOVA produces $F(5, 158)=0.19, p=0.97$, which is not statistically significant. Retention score for males across the six treatments are provided in Table 25.

Table 25: Retention Scores Descriptive Statistics for Males Across Treatment Groups

		Personification		
		None	She	He
Personalization	None	m=41% s=25% n=26	m=43% s=22% n=24	m=41% s=25% n=30
	You	m=39% s=23% n=29	m=43% s=22% n=28	m=41% s=27% n=27

Table 26 below shows the results for transfer items for females across the six treatment conditions. Five of the treatment groups yielded mean scores ranging from 45% to 52%, which are close to the 47% mean score for the traditional treatment group (no personalization (you) and no personification (s/he)). These differences of up to 5% were small compared to the standard deviations, which ranged from 25% to 31%. Comparing females in all six treatment groups using ANOVA procedures produces $F(5, 115)=1.70, p=0.14$, not a statistically significant result.

However, the combination personalization (you) and female personification (she) group produced the greatest transfer mean of 66%, which compared favorably to the standard deviations. Comparing this group to the traditional group using an independent samples t-test gives a result of $t(37)=2.33, p=0.03$, and a medium to large effect size, with Cohen's $d=0.75$.

Table 26: Transfer Scores Descriptive Statistics for Females Across Treatment

		Personification		
		None	She	He
Personalization	None	m=47% s=26% n=19	m=46% s=31% n=20	m=45% s=29% n=19
	You	m=52% s=27% n=22	m=66% s=25% n=20	m=48% s=29% n=21

Male transfer scores ranged from 42% to 57% across the six groups, with standard deviations ranging from 27% to 34%. The highest transfer mean relative to the traditional (no personalization (you) and no personification (s/he) group mean of 48% was the mean of 57% for the group with female personification (she) only.

Comparing these two groups using independent t-test procedures yields $t(52)=1.10$, $p=0.28$, not a statistically significant result. Comparing all six groups using ANOVA procedures yields $F(5, 158)=0.65$, $p=0.66$, which is also not statistically significant. Table 27 provides detailed descriptive statistics for males transfer scores across the six conditions.

Table 27: Transfer Scores Descriptive Statistics for Males Across Treatment Groups

		Personification		
		None	She	He
Personalization	None	m=48%	m=57%	m=50%
		s=29%	s=31%	s=34%
		n=26	n=24	n=30
	You	m=46%	m=47%	m=42%
		s=29%	s=33%	s=27%
		n=29	n=28	n=27

CHAPTER 5

DISCUSSION OF RESULTS

The purpose of the study was to investigate the separate and combined effects of personalization (you), personification (s/he), and gender on learning with multimedia chemistry instructional materials. First, the study is summarized, including a restatement of the research problem. Limitations of the study are then outlined, findings are discussed and research conclusions are made. Finally, implications for research and instructional design are identified.

Summary of the Study

The difficulty of learning chemistry and the negative results of this difficulty are themes throughout the research literature (Breuer, 2002; Tai et al., 2006). Furthermore, a wide array of data document the under-representation of women in most areas of science, technology, engineering, and math, the so-called STEM fields (Nosek et al., 2009; NSF, 2012; Mann & DiPrete, 2011). Women are particularly under-represented in chemistry (NSF, 2012). Research aimed at using social agency effects has focused mostly on personalization, where the learner is directly addressed as you, but none of these studies have involved chemistry (Moreno & Mayer, 2000 & 2004; Mayer, 2004). No research has been conducted on personification, where the objects under study are described using personal pronouns such as she and he, which are normally reserved for people. Without such research, there has been no opportunity to examine whether male and female students respond differently to the use of male and female personification (he versus she) in instructional materials. Given how difficult learning chemistry is, the lack of studies on personalization (you)

in chemistry, and the lack of studies on personification (s/he) and possible gender interactions in such studies, this study was conducted.

A sample of 329 high school students from four Catholic high schools in San Francisco participated in the study. Students were randomly assigned to one of six treatment groups representing two levels of the personalization (you) variable (no personalization or personalization) and three levels of the personification (s/he) variable (no personification, female personification, or male personification). Prior to the treatment, students took a pre-test to determine if they had high prior knowledge of the subject matter. Forty-four students with high prior knowledge were removed from the sample. ANOVA results indicated that the six treatment groups were statistically equivalent in terms of prior knowledge after the 44 students were removed.

Following the pre-test, students in each group watched an approximately 21 minute long multimedia instructional chemistry video on atomic structure, electron configurations, and periodic properties of atoms and elements. Three versions of the videos used personalized (you) language that addressed the learner directly using pronouns like you and yours. Two versions used personified (she) language that referred to atoms as she, two versions used personified (he) language that referred to atoms as he, and the other two versions did not use personified language and referred to atoms as its or they. The six treatments were thus: 1) the traditional group that received no personalization (you) or personification (s/he),
2) the female personified (she) group with no personalization (you),
3) the male personified (he) group with no personalization (you),

- 4) the personalization (you) group with no personification (s/he),
- 5) the combination group with both personalization (you) and female personification (she), and
- 6) the combination group with both personalization (you) and male personification (he).

After treatment, all students completed a post-test that included items designed to measure retention (recall) and transfer (problem-solving and application of knowledge). ANOVA tests indicated that there were no statistically significant differences when all students were compared across the six treatments for retention and transfer.

When retention scores for males and females were compared against each other for each of the six treatments using independent samples t tests, none of the tests yielded statistically significant results. When the transfer scores were compared for males and females, the combination personalization (you) and female personification (she) treatment video produced a significant difference indicating that females learned better than males with this treatment.

When the retention and transfer scores were compared across the six treatments for males, no statistically significant differences were detected. When the retention scores were compared across the six treatments for females, no statistically significant differences were detected. But when the transfer scores for females were tested across the different treatment conditions, a statistically significant difference was detected comparing the combination personalization (you) and female personification (she) group to the traditional group with no personalization (you) or personification

(s/he). This is the same combination treatment that produced a significant difference when comparing females and males.

Discussion

The first research question on whether personalization (you) or personification (s/he) or the combination of the two resulted in improved learning yielded small differences across treatments that are not statistically significant. Results were not significant for both retention items and transfer items.

In addressing the second research question, none of the six treatments resulted in stereotype threat conditions where females did not perform as well as males. Instead, under one treatment condition, the combination of personalization (you) with female personification (she), females scored better than males on both retention items and transfer items. The t-test analysis for females and males in this treatment approached significance for retention ($t(46)=1.52, p=0.14$). For the same males and females the t-test was significant for transfer at the 0.05 level ($t(46)=2.14, p=0.04$), but this significance can be questioned since there were six t-tests performed on the dataset and the Bonferroni correction would adjust the 0.05 significance level to 0.008. If the transfer results are considered statistically significant, the applicable Cohen's d value is 0.65, representing a medium effect size.

To address the third research question, mean retention and transfer scores for each gender were compared across the six treatments. For retention scores, no significant differences were detected. For transfer scores, no significant differences were detected for male students, but one significant difference was detected for female students using the combination personalization (you) and female

personification (she) treatment. Comparing females in this group to the traditional group with neither personalization (you) nor personification (s/he) using t procedures yields $t(37)=2.33$, $p=0.03$, and a Cohen's d (effect size) value of 0.75. Comparing all six groups for females using ANOVA procedures does not produce a statistically significant result.

In addition to the above contributions, this study adds new knowledge to Social Agency Theory, CTML, and the design principles of CTML. Firstly, this study has added a fourth study on personalization (you) that tested the use of personalization with a new subject domain (chemistry), with abstract subject matter (sub-microscopic and invisible atoms, and the model of the atom including electronic structure), and investigated possible gender differences in response to personalization (you). The study has also added a new design principle through the personification (s/he) effect where abstract objects can be described using the personal pronouns she or he and the derivatives of these pronouns to improve learning. The study has tested this new design principle alone and in combination with personalization (you) and has tested whether using she or he yields different results for female and male students. These new principles and results point to additional information about and possible adjustments to Social Agency Theory to account for why some combinations of personalization (you) and personification (s/he) seem to only affect female students. This new design principle also adds to the known body of design principles explained by CTML and this study demonstrates a synergistic interactions between two principles, personalization (you) and personification (s/he). There may be additional synergistic interactions between

In addition to adding information on personalization (you) and personification (s/he) directly, the application of these principles to much longer multimedia instructional videos highlights other aspects of multimedia learning. Previous knowledge of personalization was based on instructional games with playing times of 14-16 minutes (Moreno & Mayer, 2004) and 24-28 minutes (Moreno & Mayer, 2000) and instructional videos of only 140 seconds (Moreno & Mayer, 2004) or 60 seconds (Mayer et al., 2004). The instructional videos in this study were an average of almost 21 minutes in length (20:58) with a standard deviation of 68 seconds. The longer time videos were used to try to expand personalization (you) and personification (s/he) to more realistic and practical lengths for multimedia video explanations, especially ones on complex models or theories. The new information on possible cognitive overload from longer videos highlights the need to explore how design principles like segmenting might be put to better use to maintain medium to large effects from personalization (you), personification (s/he), and possibly other CTML design principles.

This study adds to the knowledge and understanding of stereotype threat and its effects on female science students. The finding that female students did best with the combination of personalization (you) and female personification (she) indicates that using female pronouns when personifying does not prime female students for stereotype threat, but instead results in better learning. Stereotype threat would have occurred in this study if the use of female pronouns (she, her and hers) had resulted in lower post-test scores for female students compared to female students with male or neuter pronouns (he, his, and him; or it and its). But this did not occur, instead the

opposite occurred: female students did better with female pronouns (she), at least in combination with personalization (you). Because female students did better with this combination and male students did equally well with this or other treatment variations, a combination personalized (you) and female personified (she) might be best to use for both male and female students to help all students do their best.

Future research might indicate that with better segmenting or other modifications to the videos that male students learn better with a different version. That result in combination with this study may point to more possible ways to customize learning programs for students and to even other possible social agency effects. Possibly a new effect could be found with greater individual personalization by calling students by name and called the nominalization effect.

This study also adds to our understanding of teaching the atomic model and electronic structure, key subject matter in high school and college chemistry. Personalizing (you) and personifying (s/he) the instructional materials for this abstract and impersonal subject matter (and possibly other similar subject matter) can more effectively help female students learn without hurting male students' learning. Future studies may show particular variations that can help male students learn abstract subject matter in chemistry and other sciences better as well.

Limitations

This study was limited by factors related to the sample and the methodology. The use of a convenience sample brings into question the ability to generalize results to the larger population. Students were from four Catholic private schools in San Francisco and three of these schools were single sex schools, which also limits the

generalizability of these results. Science teachers from the schools were invited to participate in the study on a volunteer basis. Twelve teachers from the schools volunteered to participate. Out of 335 students in these teachers' classes, only 6 students opted out of the study. To help reduce bias, students were randomly assigned to treatment conditions using slips of paper drawn from an envelope.

In this study, the personalization (you) condition failed to produce a statistically significant result relative to the traditional treatment condition with neither personalization (you) nor personification (s/he), even though other studies on personalization have all produced statistically significant results for transfer and many have produced statistically significant results for retention when compared to the traditional treatment (Moreno & Mayer, 2000 & 2004; Mayer, 2004). This lack of significant results for personalization (you) only may be due to confounding factors.

The first group of hypothesized confounding factors are based on the idea that the study produced cognitive memory overload for many participants. One possible factor is that the subject matter chosen from chemistry was significantly more difficult compared to the subject matter used in the other studies and that a smaller amount of subject matter or easier subject matter should have been chosen. A second possible explanation is that the treatments used in this study were much longer (mean length of 20 minutes and 58 seconds, with a standard deviation of 68 seconds) compared to the treatments in the previous studies, 140 seconds for the instructional videos on lightning formation (Moreno & Mayer, 2000) and 60 seconds for the instructional videos on lung physiology (Mayer et al., 2004). The longer treatments may have contained too much material and led to cognitive overload. Alternatively,

the longer treatments could have exceeded participant's attention spans and any effects could have been diminished by inattention. In addition to having longer treatments that could have produced learner fatigue, the use of a pre-test could have added to learner fatigue, lack of focus/attention, and memory overload. The loss of focus with longer videos and/or possible memory overload due to the presentation of too much instructional material or subject matter that was too difficult could all have reduced the expected results for the treatments with personalization (you).

One way that this possible cognitive overload could have been avoided would have been by more direct use of the segmenting principle. The instructional videos could have been separated into sections with prompts to push a button (or something similar) to continue to the next segment when learners were ready. Alternatively, participants could have been reminded at the start of the video to use pause, stop, and replay features of the video playback software to control the timing between segments. Instead of assuming that learners could or would use the playback features to control pacing, the inclusion of "go on" buttons or similar features to ensure learners use and control pacing could reduce cognitive overload and improve the study results.

In addition to possibly confounding the effects of personalization (you), cognitive overload factors could have overpowered the effects of stereotype threat. The lack of evidence for stereotype threat when comparing male and female students in most of the six treatment conditions may be more indicative of the confounding factors than a lack of stereotype threat itself. Female students may be experiencing stereotype threat in the traditional and male personification (he) conditions, but the effect of stereotype threat may be smaller than the effects from loss of focus, learner

fatigue, and/or cognitive overload from the possible confounding factors.

Stereotype effect could also not be present if the students have a low domain identity, or low sense of connection, for science in general or chemistry in particular. The more the subject domain matters to the individual, the stronger the effect of stereotype threat has been found to be (Keller, 2007; Conway-Klaasen, 2010; Aronson et al., 1998; C. M. Steele, 1998). There may have been a weaker or non-existent effect from stereotype threat since since high school students are required to study chemistry even though the subject may not matter to them.

In addition to the stereotype threat effect issues, the ages of the students in this study were younger than those in previous personalization (you) studies. Participants in this study were high school aged students (14 to 18 years old) while those in the previous personalization (you) studies were college students, mostly 18 to 22 years old. The previous studies were conducted with college students who volunteered to participate in the studies. The participants in this study were high school students who were given the option to not participate in the study, but were not required to actively volunteer to be part of the study. The permission forms used for this study allowed students and/or their parents or guardians to opt out of participating, but did not have to be signed and submitted as a requirement for participation.

In addition to age differences affecting the study outcomes, the possible cognitive overload factors could also possibly have overpowered the interaction effects between personalization (you), personification (s/he) and the student's gender. The one statistically significant treatment interaction was for female students using the combination personalization (you) and female personification (she) treatment.

Since this combination treatment had a significant result in spite of possible confounding factors while personalization (you) alone did not, it is possible that personification (s/he) alone would have produced significant results were it not for the possibly confounding factors. The removal of the possibly confounding factors by removing the pre-test, reducing the length of the treatments, using less difficult chemistry content, working with college age students, and soliciting volunteer participants could result in the detection of effects from personalization (you) alone and personification (s/he) alone. Changing the treatments could also potentially result in the detection of interaction effects between the learner's gender and the non-confounding treatments.

As well as changing the treatments, the instruments could also have limited the results from this study. The difficulty of test questions has been shown to affect the degree of stereotype threat (Keller, 2007). If the questions on the post-test were too easy, stereotype threat would not be detected. Members of stereotyped groups can perceive harder questions as evidence for negative stereotypes about themselves, but not questions that are easy. While there were no detected ceiling effects with the instruments in the study, this does not guarantee that the questions were hard enough to generate stereotype threat.

Conclusions

The experimental results indicate that there may be main effects from personalization (you) and personification (s/he) when modifying multimedia chemistry instructional materials, and there may be synergistic effects when combining the modifications as well as interactive effects when female and male

students use the materials. This experiment does not provide strong evidence for these main effects because the expected main effects for personalization (you) and personification (s/he) were not detected. However, the synergistic and interactive effect of combining personalization (you) with female personification (she) for female students did produce statistically significant results when compared with female students using treatments with neither personalization (you) nor personification (s/he). Since the combination treatment of personalization (you) and female personification (she) produced a significant result, but the better-documented personalization (you) treatment did not produce a result, even though previous studies (Moreon & Mayer, 2000 & 2004; Mayer et al., 2004) have documented the personalization (you) effect, it is possible that confounding factors reduced the sensitivity of this study to detect the main, combination, and interactive effects.

Implications

While the results of the study do not have immediate implications for modifying instructional materials and their design, the results do point to possible later modifications and design principles, pending additional research.

Research Implications

The current study suggests that there may be a relationship between post-test scores on transfer and maybe even retention items and personification (s/he) as well as personalization (you). Furthermore, the current study suggests that personification (s/he) and personalization (you) can possibly lead to greater effects when used together and that there may be an interaction between the gender of the student and the gender used in the personification (she versus he).

Because the lengths of the videos were much longer in this study than in the studies that found significant effects for personalization (you; Moreno & Mayer, 2000 & 2004; Mayer et al., 2004), future studies are needed with shorter videos to determine the optimal video length for measuring the effects for personalization (you) and personification (s/he) both separately and collectively. Also, because the complexity of the subject materials may have overwhelmed the effects of personalization (you) and personification (s/he), studies with simpler chemistry lessons are needed as well. Finally, if future studies have large sample sizes and random assignment to treatment conditions, it may be reasonable to remove the pre-test used in the study to help avoid learner fatigue and cognitive overload.

Also there is the possibility that only females will show a response to personification (s/he) and that there may be further research needed to determine why females respond and males do not. If males and females both respond to personalization (you) and only females respond to personification (s/he), and maybe only to female personification (she) and not to male personification (he), then additional research is warranted to explore the different responses and how Social Agency Theory or other theories of learning can account for differing responses. There may even be a need to modify Social Agency Theory or other learning theories to explain the differing responses.

Educational Implications

Certain modifications of instructional materials to enhance learning, especially for females, are implied in these results. Further research is needed before such methods and modifications can be recommended or should be implemented.

Should further studies confirm that personalization (you) and female personification (she) produce learning improvements for females and no difference in learning outcomes for males, then personalizing (you) and personifying (with she) multimedia instructional materials would be implied and substantiated.

With additional studies, personalization (you) is likely to be found to help both males and females, as has been found in previous studies (Moreno & Mayer, 2000 & 2004; Mayer et al., 2004) and instructional materials should be modified to include personalization (you). Should further studies confirm that female personification (she) helps females learn better without harming males' learning, then an argument can be made that most, if not all, instructional materials can be modified to include female personification (she). An advantage of this modification for designers and creators of instructional materials is that the implications still point to one version of the educational materials for all students, namely the personalized (you) and female personified (she) version, and that the implications do not point to creating two versions of the educational materials, one for males and a different one for females.

There is still a possibility that future studies may detect a gender interaction where males learn better with male personification (he) and females learn better with female personification (she), but this study does not give any indication of this interaction. Also possible is that males may learn better with female personification (she) and that one version of learning materials (personalized (you) and female personified (she)) would be the best for all students. Again, this situation would be preferable for curriculum designers and creators since one version of learning

materials would be recommended, but even if a gender interaction indicates that male and female personified (s/he) versions should be created for males and females, the differences in the learning materials is small and the two versions can be made easily. Indeed, an advantage of multimedia materials is that it is easy to create and distribute two (or even more) versions of the learning materials to students.

Summary

The purpose of this study was to determine the separate and combined effects of personalization (you) and personification (s/he) on learning outcomes for students learning with multimedia chemistry instructional materials and to determine if those effects were affected by the gender of the student. To measure learning outcomes, retention and transfer type questions were used in a post-test that participants completed after watching one of six multimedia chemistry instructional videos that corresponded to the six treatment conditions.

The current study showed that the combination of personalization (you) and female personification (she) in the instructional materials produced significantly better learning for females compared to males. The study also showed that females with this treatment (you and she) had significantly better learning results than females with a treatment with neither personalization (you) nor personification (s/he).

The other treatment conditions failed to produce significant results, even though the personalization (you) treatments were expected to do so based on previous studies (Moreno & Mayer, 2000 & 2004; Mayer et al., 2004). Three possible confounding factors related to cognitive overload and learner fatigue were postulated

to possibly have masked the effects of personalization (you) that were expected and personification (s/he) that was hypothesized.

Given that the expected effects of personalization (you) were expected and not detected, but that the combination effect from personalization (you) and female personification (she) was detected for female students, and that there are reasonable possible confounding factors that could have masked the effects of personalization (you) and personification (s/he), there is reason to conduct additional studies into personalization (you), personification (s/he), and gender. The presence of one combination effect hints at a possible situation where personification (s/he) has an additive effect when used with personalization (you) and that personification (s/he) itself may have a measurable effect on its own. The detection of the combination effect of personalization (you) and female personification (she) interacting with gender to produce better learning outcomes for females also indicates a possible way to counteract and overcome stereotype threat for females learning chemistry. Additional studies are needed to explore these possibilities.

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Appendix A: Initial Pre-Test

Pre-Test Version A

This pre-test is designed to survey and measure how much you already know about chemistry, atoms, and electrons. You might not know the answers to the questions or answer no to the survey questions. That is OK. Please answer honestly and as best you can. Thanks.

* Required

0. Please enter your ID number *

1. Have you taken a chemistry class before? *

- Yes
- No

2. Have you studied the structure of atoms before? *

- Yes
- No

3. Are you familiar with electron configurations? *

- Yes
- No

4. Do you know the differences between electron shells and subshells? *

- Yes
- No

5. Which electron configuration below is the correct configuration for Hydrogen? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

6. Which electron configuration below is the correct configuration for Neon? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

7. Which electron configuration below is the correct configuration for Aluminum? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

8. Which electron configuration below is the correct configuration for Beryllium? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

9. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which shell has eight electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

10. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which shell has nine electrons? *

- First shell
- Second shell
- Third shell

- Fourth shell
- Fifth shell

11. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has one electron? *

- 1s subshell
- 2p subshell
- 3d subshell

12. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has six electrons? *

- 1s subshell
- 2p subshell
- 3d subshell

13. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has two electrons? *

- 1s subshell
- 2p subshell
- 3d subshell

14. How many electrons can the s subshell hold? *

15. How many electrons can the p subshell hold? *

16. How many electrons can the d subshell hold? *

17. How many electrons can the f subshell hold? *

18. How many electrons can the first shell hold? *

19. How many electrons can the second shell hold? *

20. How many electrons can the third shell hold? *

21. How many electrons can the fourth shell hold? *

22. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2$
23. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2 2p^3$
24. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^1$
25. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2$
26. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2 2p^5$
27. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2 2p^4$
28. The size of sodium is given by its radius, 190 picometers. How should the size of the element below it compare to sodium?
- The radius should be smaller.
 - The radius should be the same size.
 - The radius should be larger.
29. The size of Neon is given by its radius, 38 picometers. How should the size of the element below it compare to neon?
- The radius should be smaller.
 - The radius should be the same size.
 - The radius should be larger.

Appendix B: Initial Post-Test

Post-Test Version A

This post-test is designed to survey and measure how much you have learned from the video about chemistry, atoms, and electrons. You might not know the answers to the questions. That is OK. Please answer honestly and as best you can. Thanks.

* Required

0. Please enter your ID number *

Numbering skips from 0 to 5. This is on purpose.

5. Which electron configuration below is the correct configuration for Hydrogen? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

6. Which electron configuration below is the correct configuration for Neon? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

7. Which electron configuration below is the correct configuration for Aluminum? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

8. Which electron configuration below is the correct configuration for Beryllium? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

9. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which shell has eight electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

10. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which shell has nine electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

11. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has one electron? *

- $1s$ subshell
- $2p$ subshell
- $3d$ subshell

12. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has six electrons? *

- $1s$ subshell
- $2p$ subshell
- $3d$ subshell

13. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has two electrons? *

- 1s subshell
- 2p subshell
- 3d subshell

14. How many electrons can the s subshell hold? *
15. How many electrons can the p subshell hold? *
16. How many electrons can the d subshell hold? *
17. How many electrons can the f subshell hold? *
18. How many electrons can the first shell hold? *
19. How many electrons can the second shell hold? *
20. How many electrons can the third shell hold? *
21. How many electrons can the fourth shell hold? *
22. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2$
23. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2 2p^3$
24. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^1$
25. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2$
26. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2 2p^5$
27. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2 2p^4$
28. The size of sodium is given by its radius, 190 picometers. How should the size of the element below it compare to sodium?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

29. The size of Neon is given by its radius, 38 picometers. How should the size of the element below it compare to neon?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

30. What is wrong with the following electron configuration? $0s^2 1s^2 2s^1$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells
- Nothing. The configuration is a valid configuration.

31. What is wrong with the following electron configuration? $1s^2 1p^1$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells
- Nothing. The configuration is a valid configuration.

32. What is wrong with the following electron configuration? $1s^2 2s^3 2p^4$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells
- Nothing. The configuration is a valid configuration.

33. What is wrong with the following electron configuration: $1s^2 2s^2 2p^1$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells.
- Nothing. The configuration is a valid configuration.

34. How are shells and subshells related to each other in atoms?

35. What happens when there are too many electrons to fit inside an electron shell?

36. What happens when there are too many electrons to fit inside an electron subshell?

37. How are the electron configurations of elements within element groups (such as halogens, alkali metals, and noble gases) similar to each other?

38. What happens to the electron configuration of an atom with 8 electrons if the s subshell can hold 4 electrons instead of 2?

39. How friendly was the computer that you interacted with?

- 1 [highly unfriendly]
- 2
- 3
- 4
- 5 [slightly unfriendly]
- 6 [slightly friendly]
- 7

- 8
- 9
- 10 [highly friendly]

40. How helpful is this material for learning about the electronic structure of atoms?

- 1 [highly unhelpful]
- 2
- 3
- 4
- 5 [slightly unhelpful]
- 6 [slightly helpful]
- 7
- 8
- 9
- 10 [highly helpful]

41. How interesting is this material?

- 1 [highly boring]
- 2
- 3
- 4
- 5 [slightly boring]
- 6 [slightly interesting]
- 7
- 8
- 9
- 10 [highly interesting]

42. How entertaining is this material?

- 1 [highly tiresome]
- 2
- 3
- 4

- 5 [slightly tiresome]
- 6 [slightly entertaining]
- 7
- 8
- 9
- 10 [highly entertaining]

43. How relevant is this material to you?

- 1 [highly irrelevant]
- 2
- 3
- 4
- 5 [slightly irrelevant]
- 6 [slightly relevant]
- 7
- 8
- 9
- 10 [highly relevant]

44. How difficult was the material?

- 1 [easy]
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 [difficult]

45. How much effort is required to learn the material?

- 1 [little]

- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 [much]

46. How interesting is this material compared to similar material presented by a teacher in a classroom?

- 1 [much less interesting than a teacher]
- 2
- 3
- 4
- 5 [slightly less interesting than a teacher]
- 6 [slightly more interesting than a teacher]
- 7
- 8
- 9
- 10 [much more interesting than a teacher]

47. How friendly was the computer compared to a teacher in a classroom?

- 1 [much less friendly than a teacher]
- 2
- 3
- 4
- 5 [slightly less friendly than a teacher]
- 6 [slightly friendlier than a teacher]
- 7
- 8
- 9
- 10 [much friendlier than a teacher]

48. How helpful was the computer compared to a teacher in a classroom?

- 1 [much less helpful than a teacher]
- 2
- 3
- 4
- 5 [slightly less helpful than a teacher]
- 6 [slightly more helpful than a teacher]
- 7
- 8
- 9
- 10 [much more helpful than a teacher]

49. How relevant is this material to you compared to similar material presented by a teacher in a classroom?

- 1 [much less relevant than a teacher]
- 2
- 3
- 4
- 5 [slightly less relevant than a teacher]
- 6 [slightly more relevant than a teacher]
- 7
- 8
- 9
- 10 [much more relevant than a teacher]

50. How difficult is learning this material from the computer compared to learning this material from a teacher in class?

- 1 [much less difficult than a teacher]
- 2
- 3
- 4
- 5 [slightly less difficult than a teacher]
- 6 [slightly more difficult than a teacher]

- 7
- 8
- 9
- 10 [much more difficult than a teacher]

51. How much effort does it take to learn this material from the computer compared to learning this material from a teacher in class?

- 1 [much less effort than from a teacher]
- 2
- 3
- 4
- 5 [slightly less effort than from a teacher]
- 6 [slightly more effort than from a teacher]
- 7
- 8
- 9
- 10 [much more effort than from a teacher]

52. How interesting is this material compared to similar material presented in a textbook?

- 1 [much less interesting than a textbook]
- 2
- 3
- 4
- 5 [slightly less interesting than a textbook]
- 6 [slightly more interesting than a textbook]
- 7
- 8
- 9
- 10 [much more interesting than a textbook]

53. How friendly was the computer compared to a textbook?

- 1 [much less friendly than a textbook]
- 2

- 3
- 4
- 5 [slightly less friendly than a textbook]
- 6 [slightly friendlier than a textbook]
- 7
- 8
- 9
- 10 [much friendlier than a textbook]

54. How helpful was the computer compared to a textbook?

- 1 [much less helpful than a textbook]
- 2
- 3
- 4
- 5 [slightly less helpful than a textbook]
- 6 [slightly more helpful than a textbook]
- 7
- 8
- 9
- 10 [much more helpful than a textbook]

55. How relevant is this material to you compared to similar material presented in a textbook?

- 1 [much less relevant than a textbook]
- 2
- 3
- 4
- 5 [slightly less relevant than a textbook]
- 6 [slightly more relevant than a textbook]
- 7
- 8
- 9
- 10 [much more relevant than a textbook]

56. How difficult is learning this material from the computer compared to learning this material from a textbook?

- 1 [much less difficult than a textbook]
- 2
- 3
- 4
- 5 [slightly less difficult than a textbook]
- 6 [slightly more difficult than a textbook]
- 7
- 8
- 9
- 10 [much more difficult than a textbook]

57. How much effort does it take to learn this material from the computer compared to learning this material from a textbook?

- 1 [much less effort than from a textbook]
- 2
- 3
- 4
- 5 [slightly less effort than from a textbook]
- 6 [slightly more effort than from a textbook]
- 7
- 8
- 9
- 10 [much more effort than from a textbook]

Appendix C: Content Expert Rating Sheet

Content Expert Rating Sheet

The questions on this sheet are intended for a dissertation pre-test and post-test. Two areas are being measured:

- Content knowledge (electronic structure, shells, subshells, configurations, atomic size, ionic charge, valence electrons)
- Transfer (applying knowledge about electronic structure to problems that seem different and more uncertain than the more straightforward content questions, but rely on similar underlying knowledge)

Three item types are provided.

- Standard multiple-choice items with one best choice
- Short answer items that can be answered with a number
- Longer answer items that require one or more sentences to answer

A copy of the full instrument has also been provided for your reference on the items— you are welcome to mark it up if corrections are suggested. Please return both the rating sheets and the full instrument to Shannon Halkyard (415-713-9259 or halkyard@gmail.com or shannon.halkyard@sacredsfs.org). Thank you.

Instructions for content experts:

Please select the best answer to the following questions, supplementing your answer with comments as you deem necessary. If you have any questions about the rating sheets, please contact Shannon Halkyard (415-713-9259 or halkyard@gmail.com or shannon.halkyard@sacredsfs.org) immediately.

1. Which electron configuration below is the correct configuration for Hydrogen? *

- 1s² 2s² 2p⁶
 1s² 2s² 2p³
 1s² 2s² 2p⁶ 3s² 3p¹
 1s¹
 1s² 2s²

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

2. Which electron configuration below is the correct configuration for Aluminum? *

- 1s² 2s² 2p⁶
 1s² 2s² 2p³
 1s² 2s² 2p⁶ 3s² 3p¹
 1s¹
 1s² 2s²

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

3. For the configuration 1s² 2s² 2p⁶ 3s² 3p⁶ 4s² 3d¹, which subshell has one electron? *

- 1s subshell
 2p subshell
 3d subshell

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

4. How many electrons can the s subshell hold? *

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

5. How many electrons can the p subshell hold? *

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

6. How many electrons can the second shell hold? *

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

7. How many electrons can the third shell hold? *

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

8. How many valence electrons are there in the atom with this electron configuration: 1s² 2s²

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

9. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^1$

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

10. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2$

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

11. The size of sodium is given by its radius, 190 picometers. How should the size of the element below it compare to sodium?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

12. The size of Neon is given by its radius, 38 picometers. How should the size of the element below it compare to neon?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

28. Which electron configuration below is the correct configuration for Neon? *

- 1s² 2s² 2p⁶
 1s² 2s² 2p³
 1s² 2s² 2p⁶ 3s² 3p¹
 1s¹
 1s² 2s²

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

30. Which electron configuration below is the correct configuration for Beryllium? *

- 1s² 2s² 2p⁶
 1s² 2s² 2p³
 1s² 2s² 2p⁶ 3s² 3p¹
 1s¹
 1s² 2s²

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

31. For the configuration 1s² 2s² 2p⁶ 3s² 3p⁶ 4s² 3d¹, which shell has eight electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

32. For the configuration 1s² 2s² 2p⁶ 3s² 3p⁶ 4s² 3d¹, which shell has nine electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

36. How many electrons can the d subshell hold? *

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

38. How many electrons can the fourth shell hold? *

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

40. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2 2p^3$

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

43. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2 2p^5$

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

44. What ionic charge do you expect for an element with this electron configuration in its uncharged (neutral) state: $1s^2 2s^2 2p^4$

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

46. What is wrong with the following electron configuration? $0s^2 1s^2 2s^1$

- The configuration includes a shell that does not exist.
 The configuration includes a subshell that does not exist.
 The configuration includes too many electrons in one of the subshells.
 The configuration includes too few electrons in one of the subshells
 Nothing. The configuration is a valid configuration.

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

47. What is wrong with the following electron configuration? 1s2 1p1

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells
- Nothing. The configuration is a valid configuration.

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

48. What is wrong with the following electron configuration? 1s² 2s³ 2p⁴

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells.
- Nothing. The configuration is a valid configuration.

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

49. What is wrong with the following electron configuration: 1s2 2s2 2p1

- The configuration includes a shell that does not exist.
 The configuration includes a subshell that does not exist.
 The configuration includes too many electrons in one of the subshells.
 The configuration includes too few electrons in one of the subshells
 Nothing. The configuration is a valid configuration.

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

50. How are shells and subshells related to each other in atoms?

--

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

52. What happens to the electron configuration of an atom with 8 electrons if the s subshell can hold 4 electrons instead of 2?

1. Does the question clearly relate to one of the two areas being measured? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
2. In which content area does it best fit? <input type="checkbox"/> Content knowledge <input type="checkbox"/> Transfer Comment:	
3. Is the intent of the question clear? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
4. Is the language of the question clear and unambiguous? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
5. Is the question clear and unambiguous in its content? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
6. Is there only one correct answer? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
7. Is the question written at an appropriate level for high school chemistry students? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
8. Is the format of the question (e.g. use of terms, specific situation cited, grammar) clear and understandable? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No
9. Do you suggest a change in format? Comment:	<input type="checkbox"/> Yes <input type="checkbox"/> No

Appendix D: Video Content Expert Rating Sheet

Video Content Expert Rating Sheet

The questions on this sheet are intended for a dissertation video treatment. In order for the video to be effective, any problems with layout and design need to be identified and addressed:

- Extraneous visual on-screen material
- Extraneous narrative elements
- Redundant text
- Improperly timed images and audio
- Related text and pictures that are placed too far away from each other
- Failures to provide verbal cues that make the structure of the presentation clear to the learner

This sheet includes the screen images and the audio script that accompanies each image so that you can mark on the script and on the images any problems or recommended changes.

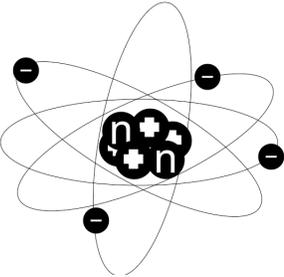
Please return both the rating sheets to Shannon Halkyard (415-713-9259 or halkyard@gmail.com or shannon.halkyard@sacredsfsf.org). Thank you.

Instructions for content experts:

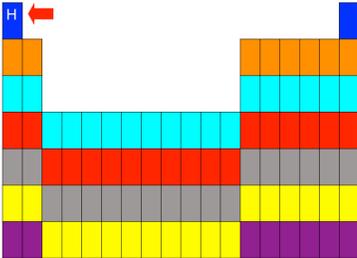
Please answer the following questions, supplementing your answer with comments as you deem necessary. If you have any questions about the rating sheets, please contact Shannon Halkyard (415-713-9259 or halkyard@gmail.com or shannon.halkyard@sacredsfsf.org) immediately.

Image	Script
Atomic Structure	Welcome to an instructional video on Atomic Structure

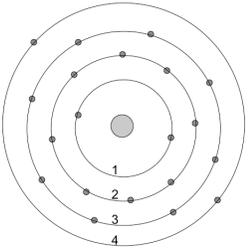
Please identify any extraneous material that should be excluded from this image or its accompanying narration.
Please circle any text on this image that is redundant with the audio narration.
Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.
Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> • Did any sentence(s) preview this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____

Image	Script
	<p>Introduction to Atoms</p> <p>Atoms are the smallest unit of matter that you can still consider an element. You can't call a particle that is smaller than an atom an element, but instead you would call her an elementary particle or a subatomic particle.</p> <p>Atoms are therefore also the smallest units of the elements.</p> <p>If you could see an atom, you would see that she consists of electrons and a nucleus with neutrons and protons. When you study chemistry, you are primarily concerned with her electrons.</p>

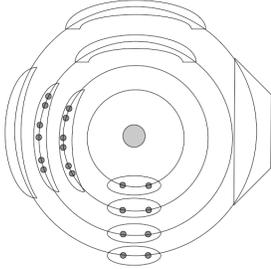
<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> • Did any sentence(s) preview this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____

Image	Script
	<p>The Periodic Table</p> <p>When you study them, you find that the number of electrons is different for each element and that each element on the periodic table is arranged in order from the element whose atoms contain only one electron (hydrogen) to the element whose atoms contain 118 electrons (ununoctium). You can also see that all those elements are in order following from left to right for each row, following the rows from top to bottom.</p> <p>You can use models of the electronic structure of atoms to explain the chemical properties of elements when you describe how the electrons are arranged around the nucleus.</p>

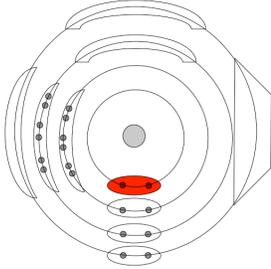
<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
	<p>Shells and subshells</p> <p>Your model of electronic structure begins with electrons divided into primary groupings call shells. Those shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within each shell, you see electrons grouped into subshells.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
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Image	Script
	<p>The number of subshells varies for each shell, but follows a pattern that you can follow. Part of your pattern is that the number of shells is equal to the number of each shell.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>Here is your pattern for shells. The first shell, she has one subshell</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

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 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>while the second shell, she has two subshells,</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

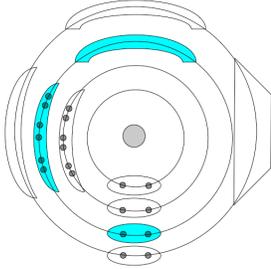
Please circle any text on this image that is redundant with the audio narration.

Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.

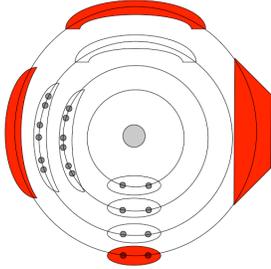
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Are there sufficient verbal indicators prior to this image, such as:

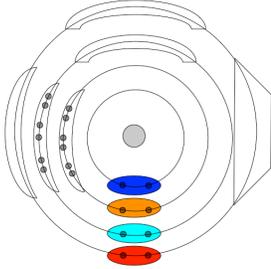
- Did any sentence(s) preview this section?
 - Yes _____
 - No _____
- Did a phrase serve as a heading for this section?
 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>the third shell, she has three subshells,</p>

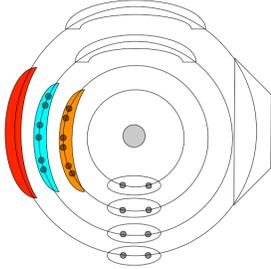
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Image	Script
	<p>and so on.</p> <p>How many shells do you think the fourth shell has? The fifth shell?</p> <p>Subshells don't have numbers, but instead they have letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.</p>

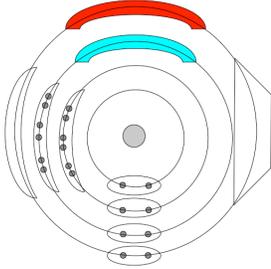
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Image	Script
	<p>Within the shells, you find that the first subshell in every shell of electrons is the s subshell. Her letter S stands for sharp.</p>

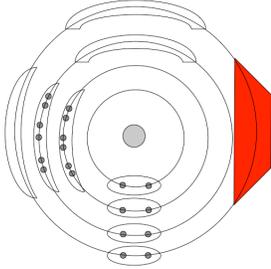
<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>Then you find the second subshell, which is found in every electron shell except for the first shell is the p subshell. Her letter P stands for principle.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>Your third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. Her letter D stands for diffuse.</p>

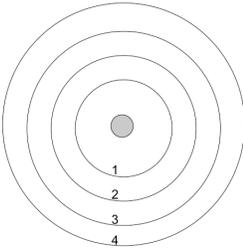
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Image	Script
	<p>The fourth subshell, found in the fourth shell and beyond, is the f subshell. Her letter F stands for fine.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
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Image	Script
<p>s p d f g h i j k</p>	<p>After the f subshell, you will find more subshells in the larger shells, but the letters for those subshells are g, h, i, and so on, following the alphabet. Their letters are not related to any names used by early chemists.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>Electrons and shells</p> <p>Next you find that there are a limited number of electrons in each shell in the atomic model.</p> <p>Only two electrons can fit in your atom's first shell.</p>

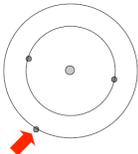
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Image	Script
<p>Hydrogen</p> 	<p>The first element, Hydrogen, has one electron and she is located in the first shell.</p>

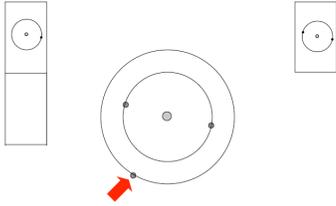
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<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
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Image	Script
<p style="text-align: center;">Helium</p> 	<p>The second element, Helium, has two electrons and they are located in the first shell. What do you think happens for an element with three electrons?</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
<p style="text-align: center;">Lithium</p> 	<p>The third element, Lithium, has three electrons, more than the maximum for the first shell, so two of them are in the first shell and one of them in the second shell.</p>

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Image	Script
	<p>You can see this change to the second shell paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

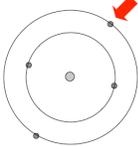
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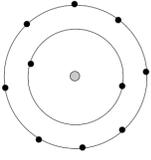
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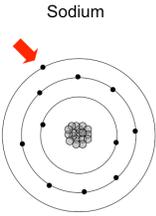
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 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
<p style="text-align: center;">Beryllium</p> 	<p>Your fourth element, Beryllium, has four electrons, two of them in the first shell and two of them in the second shell.</p> <p>You can see that the second shell can hold a maximum of eight electrons, so the elements in period use the second shell up to the tenth element,</p>

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Image	Script
<p style="text-align: center;">Neon</p> 	<p>Neon, she has ten electrons, two electrons in the first shell and eight electrons in the second shell. What do you think happens for an element with eleven electrons?</p>

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Image	Script
<p style="text-align: center;">Sodium</p> 	<p>When you examine the eleventh element, sodium, she has more electrons than the first and second shells can hold and her eleventh electron is in the third shell.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

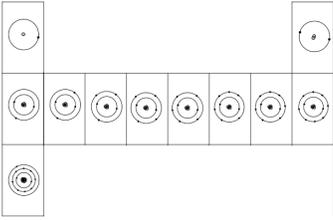
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 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>You can see the change from the second electron shell to the third electron shell paralleled in the periodic table by a shift from the second period to the third period.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

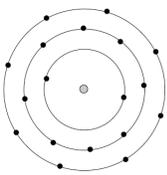
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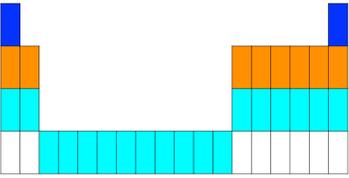
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Image	Script
<p style="text-align: center;">Argon</p> 	<p>You can also see that the pattern of electrons being added for the third period follows the same pattern as the second period to element 18, Argon.</p> <p>Be careful here as Argon is not the last element to add electrons to the third shell even though she is the last element in period three.</p>

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Image	Script
	<p>You can look and see the periodic table showing a second pattern of the atomic model where the fourth period of the table represents parts of her third and fourth shells of electrons. Your second pattern for the atomic model is her pattern for her subshells .</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

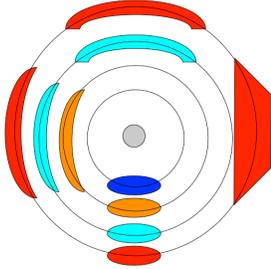
Please circle any text on this image that is redundant with the audio narration.

Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.

Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?

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 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>Electrons in the subshells</p> <p>You can find that each atom has a limited number of electrons in each of her shells and also in each of her subshells.</p> <p>You will also find atoms fill their shells with electrons in numerical order. Atoms also fill their subshells within each shell with electrons in the order s, p, d, f, g, and so on.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

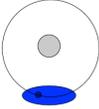
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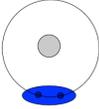
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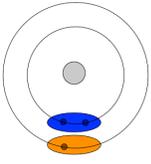
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 - No _____
- Did a phrase serve as a heading for this section?
 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
<p>Hydrogen</p> 	<p>If you could see the atom, you would see that Hydrogen has her one electron in her first subshell in her first shell, called her 1s subshell.</p>

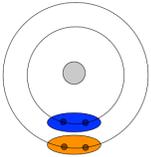
<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
<p>Helium</p>  <p>The diagram shows a central grey nucleus with a plus sign. Two blue circles representing electrons are positioned at the bottom of a larger circle representing the 1s subshell. The word 'Helium' is written above the diagram.</p>	<p>Then you would see that Helium has her two electrons in her first subshell in her first shell, called her 1s subshell.</p>

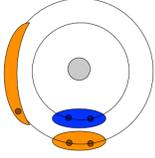
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<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes ____ <li>○ No ____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes ____ <li>○ No ____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes ____ <li>○ No ____

Image	Script
<p style="text-align: center;">Lithium</p> 	<p>But you would find that Lithium has three electrons, two in her 1s subshell and one in her first subshell in the second shell, called the 2s subshell.</p>

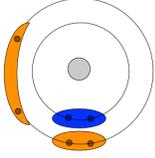
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Image	Script
<p style="text-align: center;">Beryllium</p> 	<p>Beryllium has four electrons, two in her 1s subshell and two in her 2s subshell. What do you think happens for an element with five electrons?</p>

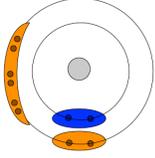
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<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> • Did any sentence(s) preview this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____

Image	Script
<p style="text-align: center;">Boron</p> 	<p>When you get to Element number five, Boron, she has five electrons with two in her 1s subshell and two in her 2s subshell. The fifth electron is located in the second subshell of her second shell, called the 2p subshell.</p>

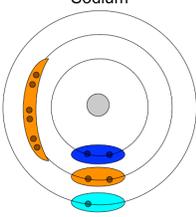
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Image	Script
<p style="text-align: center;">Carbon</p> 	<p>You see that Element six, Carbon, continues the pattern, with her six electrons, two in her 1s subshell, two in her 2s subshell, and two in her 2p subshell.</p>

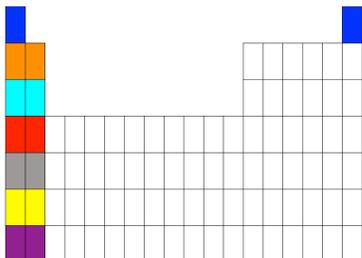
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Image	Script
<p style="text-align: center;">Neon</p> 	<p>Eventually you have the 2p subshell can hold a maximum of six electrons and element ten, Neon, is the element with her 2p subshell full. What do you think happens for sodium with her eleven electrons?</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
<p style="text-align: center;">Sodium</p> 	<p>When the next element has eleven electrons, you see her last electron is in the first subshell of her third shell, called the 3s subshell.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>The s block elements</p> <p>Notice that each of the first two elements of every period in the periodic table has her outermost electrons in s subshells, so elements in the first two columns of the periodic table are called s block elements.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

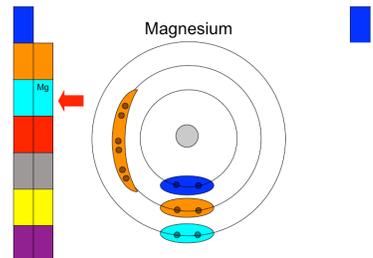
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- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>The twelfth element, Magnesium, is part of the s block, with her outermost two electrons in the 3s subshell.</p>

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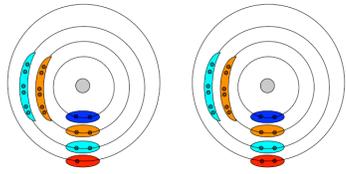
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 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
<p style="text-align: center;">Aluminum</p>	<p>You can see the next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of her third shell, the 3p subshell.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>The p block elements</p> <p>Similar to how each of the first two elements of each period had her outermost electron located in an s subshell, see that each of the last six elements of each period has her outermost electrons located in a p subshell. These elements are called the p block elements and you can explain many properties of these elements using p subshells.</p>

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Image	Script
<p style="text-align: center;">Potassium Calcium</p> 	<p>Your first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

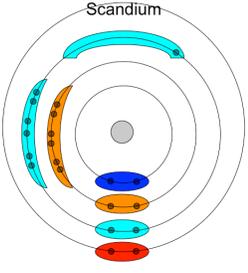
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Image	Script
	<p>But you see the next element, Scandium, has her next electron added the outermost subshell—and this subshell is part of her third shell instead of the fourth. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells. See that Scandium has two electrons in the 4s subshell, following the pattern of the two elements before her, but she has one electron in the third subshell of her third shell, called the 3d subshell.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

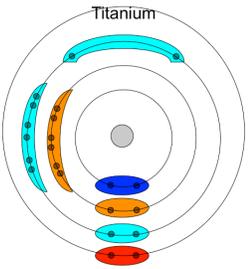
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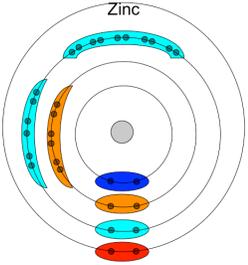
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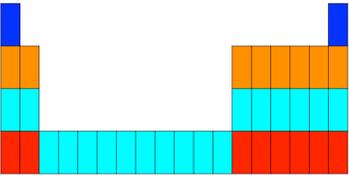
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 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>Notice that the next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d and</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>Linking the electron arrangement to the Periodic Table</p> <p>See how this pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

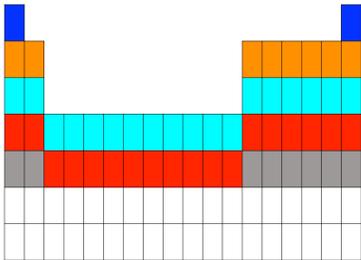
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 - No _____

Image	Script
	<p>You can see how the pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.</p> <p>What do you think the name is for the group of elements in the middle of the periodic table?</p>

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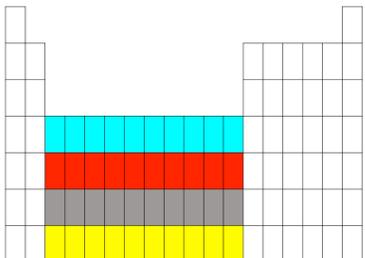
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 - No _____
- Did a phrase serve as a heading for this section?
 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>The d block elements</p> <p>You can call the group of elements in the middle ten columns of the periodic table the d block because each of these elements has between one and ten electrons in her d subshell.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

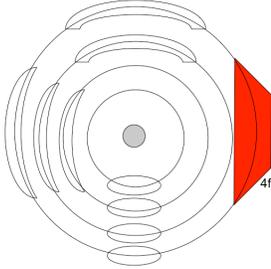
Please circle any text on this image that is redundant with the audio narration.

Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.

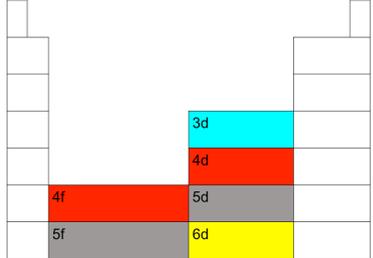
Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?

Are there sufficient verbal indicators prior to this image, such as:

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 - No _____
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 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to their d subshells and the f subshells of their inner shells.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
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Image	Script
	<p>You can see how this pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. Also see how the periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

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 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
 <p>The image shows a simplified periodic table with columns of varying heights. The 6s subshell is highlighted in three colors: red, grey, and yellow. The text '6 s' is written in the first cell of the red block.</p>	<p>Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

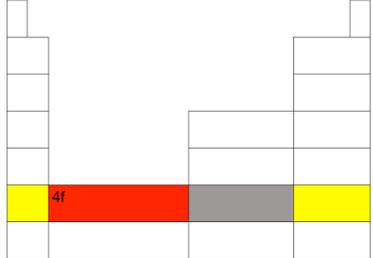
Please circle any text on this image that is redundant with the audio narration.

Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.

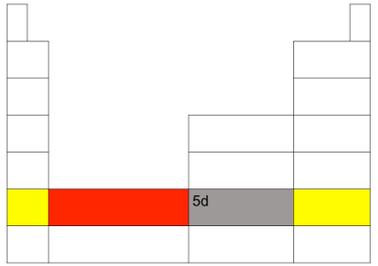
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Are there sufficient verbal indicators prior to this image, such as:

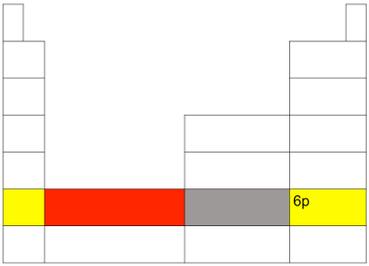
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 - No _____
- Did a phrase serve as a heading for this section?
 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
	<p>Notice how before filling the 5d subshell, the next fourteen elements, Lanthanum to Ytterbium, fill their 4f subshells.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
 <p>The image shows a simplified periodic table with four columns of elements. The second and third columns are highlighted in red and yellow, representing the 5d subshell. The text '5d' is written in the center of the red and yellow area.</p>	<p>Then the next ten elements fill their 5d subshell and</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
	<p>The last six elements fill their 6p subshell. What do you think the order of the subshells for the seventh period is?</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
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Image	Script
	<p>The elements in period seven follow the same pattern as those in period six.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

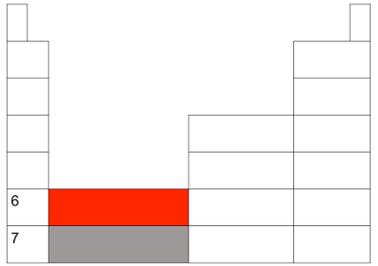
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Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.

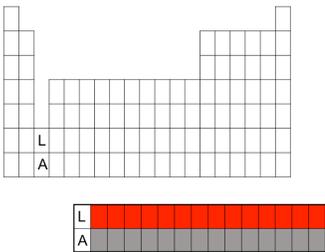
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 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
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 - No _____

Image	Script
	<p>The f block elements Notice that even though these elements that fill their f subshells would ideally be located in the middle left of the periodic table,</p>

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Image	Script
	<p>they are usually placed at the bottom of most periodic tables. You can call them the f block elements. You can also call them the Lanthanides and Actinides after the elements that begin each row.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

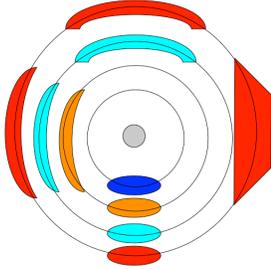
Please circle any text on this image that is redundant with the audio narration.

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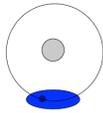
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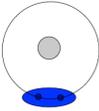
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Image	Script
	<p>Electron configurations</p> <p>You can replace drawing diagrams for the electronic structure of atoms can be represented with a written shorthand notation called electron configuration. Your electron configuration represents the shells and subshells that have electrons with letter and number combinations: 1s, 2s, 2p, 3s, 3p and so on. After each letter, you put a superscript number that indicates how many electrons are located in that subshell. You will see that the pattern for electron configurations is the most straightforward for the first 18 elements.</p>

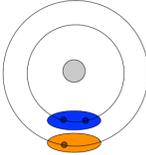
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Image	Script
<p>Hydrogen $1s^1$</p> 	<p>Hydrogen has a configuration of $1s^1$ because she has one electron in the s subshell in her first shell.</p>

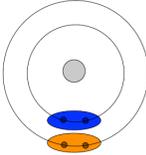
<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
<p>Helium $1s^2$</p>  <p>The diagram shows a central grey nucleus with two protons and two neutrons. Two electrons are shown as blue spheres with minus signs, orbiting the nucleus in a circular path. The text 'Helium 1s²' is positioned above the diagram.</p>	<p>Helium has a configuration of $1s^2$ because she has two electrons in the s subshell in her first shell.</p> <p>What do you think the configuration is for an element who has three electrons?</p>

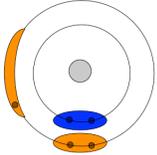
<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
<p>Lithium $1s^2 2s^1$</p> 	<p>Notice that since there is no 1p subshell, Lithium has a configuration of $1s^2 2s^1$ because she has two electrons in the s subshell in her first shell and one electron in the s subshell of her second shell.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
<p>Beryllium $1s^2 2s^2$</p> 	<p>Beryllium continues the pattern with $1s^2 2s^2$.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
<p>Boron $1s^2 2s^2 2p^1$</p> 	<p>Now you can see that since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^2 2s^2 2p^1$ with two electrons in the s subshell in her first shell, two electrons in the s subshell of her second shell and one electron in the p subshell of her second shell.</p>

Please identify any extraneous material that should be excluded from this image or its accompanying narration.

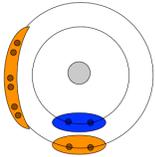
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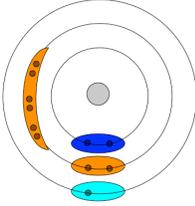
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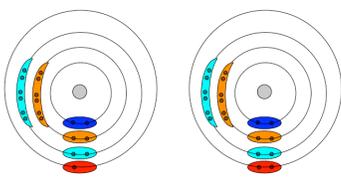
- Did any sentence(s) preview this section?
 - Yes _____
 - No _____
- Did a phrase serve as a heading for this section?
 - Yes _____
 - No _____
- Was there any intonation on linking words and phrases, such as “because of this”?
 - Yes _____
 - No _____

Image	Script
<p>Neon $1s^2 2s^2 2p^6$</p> 	<p>When you continue across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^2 2s^2 2p^6$. What do you think the configuration is for sodium with her eleven electrons?</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
<p>Please circle any text on this image that is redundant with the audio narration.</p>
<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> <li>• Did any sentence(s) preview this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____ <li>• Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> <li>○ Yes _____ <li>○ No _____

Image	Script
<p>Sodium $1s^2 2s^2 2p^6 3s^1$</p> 	<p>Then when you begin the third period with sodium, there is configuration $1s^2 2s^2 2p^6 3s^1$ for her eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.</p>

<p>Please identify any extraneous material that should be excluded from this image or its accompanying narration.</p>
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Image	Script
<p>Potassium $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$</p> <p>Calcium $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$</p> 	<p>Configuration changes in the fourth period For the fourth period, you will see the pattern changes with the d block elements. The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.</p>

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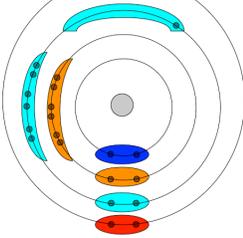
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Image	Script
<p>Scandium $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$</p> 	<p>With scandium and the other d block elements, you see the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.</p>

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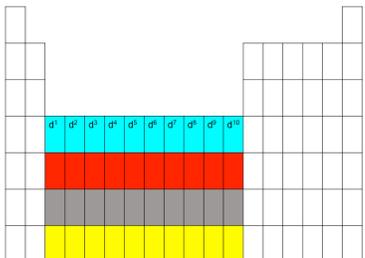
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Image	Script
	<p>You will find the general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.</p>

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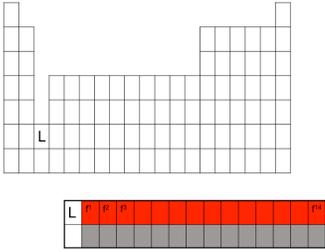
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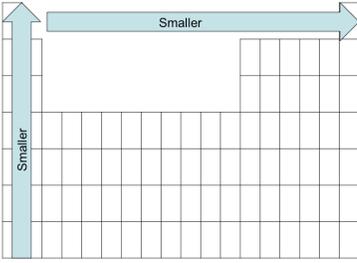
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Image	Script
	<p>The other d block elements follow the same general pattern as those in the fourth period do, but you find yet another pattern layer is added for the f block elements, beginning with Lanthanum in period 6.</p>

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Image	Script
	<p>Electron arrangement and atomic size</p> <p>You can use the arrangement of electrons into shells and subshells to explain patterns in the sizes of the atoms for different elements.</p> <p>Atomic size decreases in element families from the largest at the bottom of the periodic table to the smallest at the top, and atomic size also decreases going across the periods of the table from left to right.</p>

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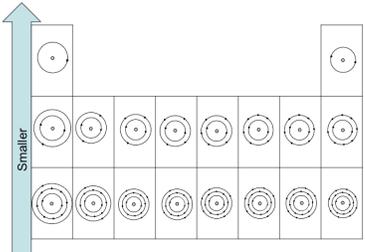
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Image	Script
	<p>Your electronic structure explanation for the first pattern in atomic size is that if an element is located below another element on the periodic table, then she has more shells of electrons and she is larger.</p> <p>Is an element in the third period larger or smaller than the element above her?</p>

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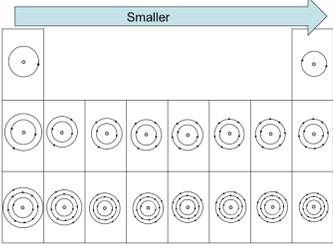
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Image	Script
	<p>For your second pattern, you can explain with electronic structure that while an element to the right side of the periodic table has more electrons than elements to her left do, both she and the elements to the left have the electrons in the same shell of the atom and</p>

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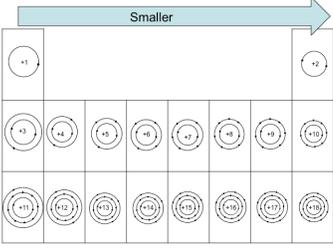
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Image	Script
	<p>Because an element to the right has protons, the electrons in her outermost shell feel a stronger attractive force from her nucleus and are therefore closer to the nucleus, making her smaller.</p> <p>Is an element at the far right of the periodic table larger or smaller than the element to her left?</p>

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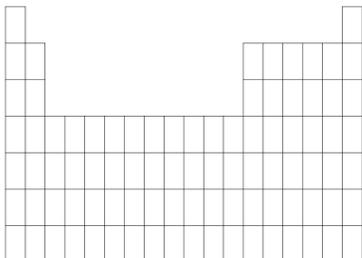
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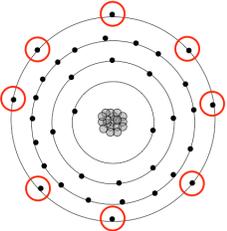
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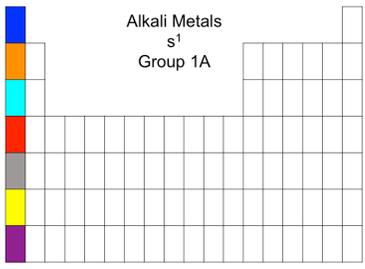
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Image	Script
	<p>Element groups and electronic structure The elements were originally grouped in the periodic table based on their properties. You can use the model of electronic structure to explain their properties.</p>

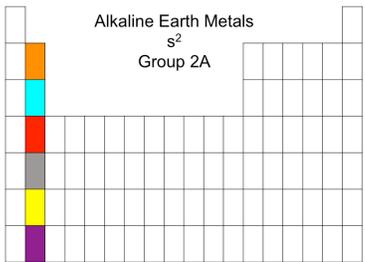
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Image	Script
	<p>You will find that the cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of an atom and which are involved in her chemical reactions.</p>

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Image	Script
 <p>Alkali Metals s¹ Group 1A</p>	<p>Groups of elements, valence electrons, and common ionic charges</p> <p>Your first group of elements in the periodic table is the alkali metals, each of which has one valence electron in her outermost shell. That electron is always located in the s subshell of her outermost shell and each alkali element is described as an s¹ element. When you remove her one valence electron an alkali metal forms a cation with +1 charge.</p>

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Image	Script
 <p>Alkaline Earth Metals s² Group 2A</p>	<p>Your second group of elements in the periodic table is the alkaline earth metals, each of which has two valence electrons. Each of these elements is described as an s² element and each forms a cation with a +2 charge when you remove her two valence electrons.</p>

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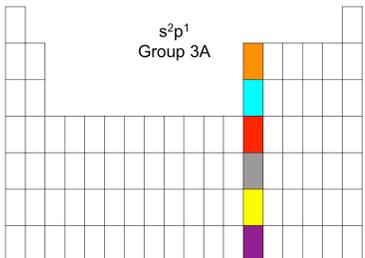
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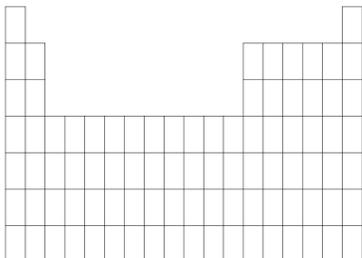
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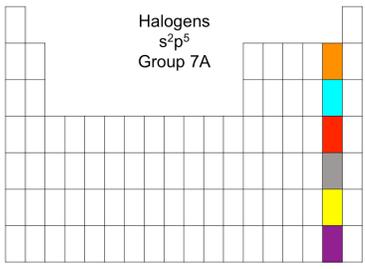
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Image	Script
 <p style="text-align: center;">s^2p^1 Group 3A</p>	<p>With each element in group 3A of the periodic table, you find she has three electrons in her valence shell and she forms a cation with a +3 charge. Notice that because only two electrons can be in her s subshell, she has a third electron in a p subshell and has an s^2p^1 configuration. Does an element that loses some of her electrons become positively or negatively charged?</p>

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Image	Script
	<p>Your elements on the right side of the periodic table also form ions with similar charges when they gain electrons.</p>

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Image	Script
 <p>Halogens s^2p^5 Group 7A</p>	<p>You saw before that each of the halogens in group 7A of the periodic table has seven valence electrons in an s^2p^5 configuration. Each halogen commonly forms an anion with one more electron, giving her a -1 charge. You can explain with Atomic theory that she has an unoccupied space in her valence electron shell and enough attraction from her nucleus to attract and keep an extra electron in her valence shell, making her into an anion.</p>

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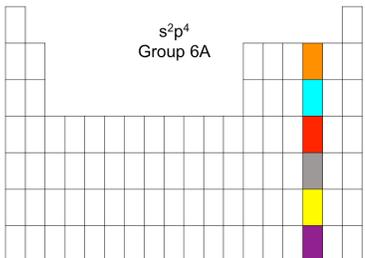
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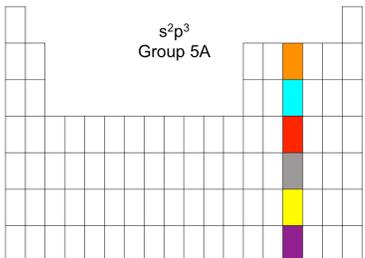
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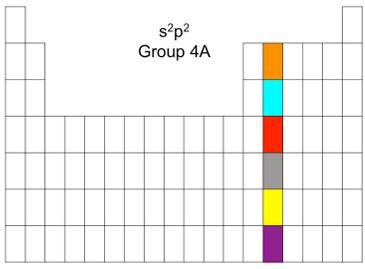
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Image	Script
 <p style="text-align: center;">s^2p^4 Group 6A</p>	<p>Each of your elements in group 6A commonly forms an anion with two more electrons, giving her a -2 charge. Notice that this charge parallels the fact that she has an s^2p^4 configuration with room for two additional electrons in her outermost p subshell.</p>

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Image	Script
 <p style="text-align: center;">s^2p^3 Group 5A</p>	<p>Each of your elements in group 5A commonly form anions with three more electrons, giving her a -3 charge. Notice that this charge parallels the fact that she has an s^2p^3 configuration with room for three additional electrons in her outermost p subshell.</p> <p>Does an element that gains electrons become positively or negatively charged?</p>

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Image	Script
	<p>Your elements in group 4A have a more complicated pattern. When one of these elements forms an anion with four more electrons, she has a -4 charge. Notice that this charge parallels the fact that she has an s^2p^2 configuration with room for four additional electrons in her outermost p subshell. But also be aware that some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.</p>

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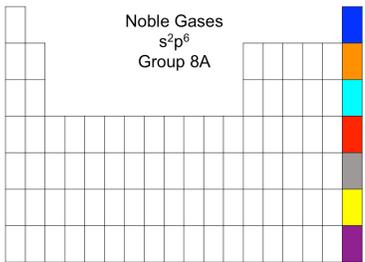
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Image	Script
 <p>Noble Gases s²p⁶ Group 8A</p>	<p>On the far right of the periodic table you have the noble gases, with full valence shells holding 2 s and 6 p electrons. You may know that these elements do not normally form ions or ionic compounds because it is energetically unfavorable for any of them to add an additional electron to a new valence shell when all of her current electrons partially counteract the attractive force of her nucleus. You can call this counteraction electron shielding in technical chemistry language.</p> <p>How is an element's group related to the number of valence electrons in her atoms?</p>

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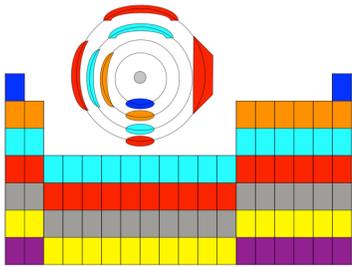
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Image	Script
	<p>Conclusion</p> <p>Atomic sizes and common ionic charges are two of many properties of atoms that you can explain using atomic models of electron configurations with shells and subshells. You have seen how these properties and the model of the atom parallel the organization and structure of the periodic table. The model of the atom you now know and the structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to removed electrons from atoms. You can use the periodic table and the atomic model to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.</p>

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<p>Please indicate if the timing of this image and the narration are correct. If the timing could be improved, please indicate how.</p>
<p>Are any of the text or pictures in this screen image placed too far away from each other? What elements of the image should be moved and where?</p>
<p>Are there sufficient verbal indicators prior to this image, such as:</p> <ul style="list-style-type: none"> • Did any sentence(s) preview this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Did a phrase serve as a heading for this section? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____ • Was there any intonation on linking words and phrases, such as “because of this”? <ul style="list-style-type: none"> ○ Yes _____ ○ No _____

Appendix E: Pre-Test Final

Pre-Test

This pre-test is designed to survey and measure how much you already know about chemistry, atoms, and electrons. You might not know the answers to the questions or answer no to the survey questions. That is OK. Please answer honestly and as best you can. Thanks.

* Required

0. Please enter your ID number *

1. Which electron configuration below is the correct configuration for Hydrogen? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2$
- $1s^1$
- $1s^2 2s^2$

2. Which electron configuration below is the correct configuration for Aluminum? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

3. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has one electron? *

- 1s subshell
- 2p subshell
- 3d subshell

4. What's the maximum number of electrons an s subshell can hold? *

5. What's the maximum number of electrons a p subshell can hold? *

6. What's the maximum number of electrons that the second shell can hold? *

7. What's the maximum number of electrons that the third shell can hold? *

8. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2 2p^2$

9. When it makes an ion, do you expect a positive or negative charge for an element with this electron configuration: $1s^2 2s^1$

10. When it makes an ion, do you expect a positive or negative charge for an element with this electron configuration: $1s^2 2s^2$

11. The size of sodium is given by its radius, 190 picometers. How should the size of the element below it on the periodic table compare to sodium?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

12. The size of Neon is given by its radius, 38 picometers. How should the size of the element below it on the periodic table compare to neon?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

Appendix F: Post-Test Final

Post-Test

This post-test is designed to survey and measure how much you have learned from the video about chemistry, atoms, and electrons. You might not know the answers to the questions. That is OK. Please answer honestly and as best you can. Thanks.

* Required

0. Please enter your ID number *

The numbering skips in this section. Don't worry about this being wrong. The numbering is done this way on purpose.

32. What is wrong with the following electron configuration? $1s^2 2s^3 2p^4$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells.
- Nothing. The configuration is a valid configuration.

5. Which electron configuration below is the correct configuration for Hydrogen? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2$
- $1s^1$
- $1s^2 2s^2$

6. Which electron configuration below is the correct configuration for Neon? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

7. Which electron configuration below is the correct configuration for Aluminum? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

8. Which electron configuration below is the correct configuration for Beryllium? *

- $1s^2 2s^2 2p^6$
- $1s^2 2s^2 2p^3$
- $1s^2 2s^2 2p^6 3s^2 3p^1$
- $1s^1$
- $1s^2 2s^2$

9. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which shell has eight electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

10. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which shell has nine electrons? *

- First shell
- Second shell
- Third shell
- Fourth shell
- Fifth shell

11. For the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$, which subshell has one electron? *

- $1s$ subshell
- $2p$ subshell
- $3d$ subshell

14. What's the maximum number of electrons an s subshell can hold? *
15. What's the maximum number of electrons a p subshell can hold? *
16. What's the maximum number of electrons a d subshell can hold? *
19. What's the maximum number of electrons that the second shell can hold? *
21. What's the maximum number of electrons that the fourth shell can hold? *
22. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2 2p^2$
23. How many valence electrons are there in the atom with this electron configuration: $1s^2 2s^2 2p^3$

28. The size of sodium is given by its radius, 190 picometers. How should the size of the element below it on the periodic table compare to sodium?

- The radius should be smaller.
- The radius should be the same size.
- The radius should be larger.

30. What is wrong with the following electron configuration? $0s^2 1s^2 2s^1$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells.
- Nothing. The configuration is a valid configuration.

31. What is wrong with the following electron configuration? $1s^2 1p^1$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells.
- Nothing. The configuration is a valid configuration.

33. What is wrong with the following electron configuration: $1s^2 2s^2 2p^1$

- The configuration includes a shell that does not exist.
- The configuration includes a subshell that does not exist.
- The configuration includes too many electrons in one of the subshells.
- The configuration includes too few electrons in one of the subshells.
- Nothing. The configuration is a valid configuration.

34. In an atom, what is the difference between shells and subshells?

36. What happens when there are too many electrons to fit inside an electron subshell?

38. What would the electron configuration be for an atom with 8 electrons if the s subshell could hold 4 electrons instead of just 2?

What is your gender *

- Female
- Male

Appendix G: Treatment Scripts

Atomic Structure Script: Traditional

Slide 1: Title Slide

Welcome to an instructional video on Atomic Structure

Slide 2: Introduction

Introduction to Atoms

Atoms are the smallest unit of matter that can still be an element. Particles that are smaller than atoms are no longer elements, but are called elementary particles or subatomic particles.

Atoms are therefore also the smallest units of the elements.

Atoms consist of electrons and a nucleus with neutrons and protons, but the study of chemistry is primarily concerned with the electrons.

Slide 3: Periodic table

The Periodic Table

The number of electrons is different for each element, but the elements on the periodic table are arranged in order from the element with atoms containing only one electron (hydrogen) to the element with atoms that contain 118 electrons (ununoctium). All the elements are in order following from left to right for each row, following the rows from top to bottom.

Models of the electronic structure of atoms are used to explain the chemical properties of elements through descriptions of how the electrons are arranged around the nucleus.

Slide 4: Shells

Shells and subshells

The model of electronic structure begins with electrons divided into primary groupings called shells. The shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within the shells, electrons are grouped into subshells.

Slide 5: Subshells

The number of subshells varies for each shell, but follows a pattern. The number of subshells is equal to the number of each shell.

Slide 6:

The first shell has one subshell

Slide 7:

while the second shell has two subshells,

Slide 8:

the third shell has three subshells,

Slide 9:

and so on.

How many shells does the fourth shell have? The fifth shell?

Subshells are not numbered, but are instead given letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.

Slide 10: s subshells

The first subshell in every shell of electrons is the s subshell. S stands for sharp.

Slide 11: p subshells

The second subshell, which is found in every electron shell except for the first shell is the p subshell. P stands for principle.

Slide 12: d subshells

The third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. D stands for diffuse.

Slide 13: f subshells

The fourth subshell, found in the fourth shell and beyond, is the f subshell. F stands for fine.

Slide 14: s, p, d, f, g, h, i...

After the f subshell, there are more subshells in the larger shells, but the names of those subshells are g, h, i, and so on, following the alphabet. The letters for these subshells are not related to any names used by early chemists.

Slide 15: Shells only

Electrons and shells

There are a limited number of electrons in each shell in the atomic model.

The first shell can hold a maximum of two electrons.

Slide 16: Hydrogen

The first element, Hydrogen, has one electron located in the first shell.

Slide 17: Helium

The second element, Helium, has two electrons located in the first shell.

What happens for an element with three electrons?

Slide 18: Lithium

The third element, Lithium, has three electrons, more than the maximum for the first shell, so there are two electrons in the first shell and one electron in the second shell.

Slide 19: Periodic table period change

This change to the second shell is paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.

Slide 20: Beryllium

The fourth element, Beryllium, has four electrons, two electrons in the first shell and two electrons in the second shell.

The second shell can hold a maximum of eight electrons, so the elements in period two use the second shell up to the tenth element,

Slide 21: Neon

Neon, which has ten electrons, two electrons in the first shell and eight electrons in the second shell.

What happens for an element with eleven electrons?

Slide 22: Sodium

The eleventh element, sodium, has more electrons than the first and second shells can hold and has the eleventh electron in the third shell.

Slide 23: Periodic table period change

The change from the second electron shell to the third electron shell is paralleled in the periodic table by a shift from the second period to the third period.

Slide 24: Argon

The pattern of electrons being added for the third period follows the same pattern as the second period up to element 18, Argon.

Argon is not the last element to add electrons to the third shell even though it is the last element in period three.

Slide 25: Periodic table

This is because the periodic table matches a second pattern of the atomic model where the fourth period of the table represents parts of the third and fourth shells of electrons in the atomic model. The second pattern of the atomic model is the pattern for the subshells.

Slide 26: Generic subshells with electrons

Electrons in the subshells

There are a limited number of electrons in each shell and also in each subshell in the atomic model.

Electrons fill the shells in numerical order. Electrons fill the subshells within each shell in the order s, p, d, f, g, and so on.

Slide 27: Hydrogen

Hydrogen has one electron in the first subshell in the first shell, called the 1s subshell.

Slide 28: Helium

Helium has two electrons in the first subshell in the first shell, called the 1s subshell.

Slide 29: Lithium

Lithium has three electrons, two in the 1s subshell and one in the first subshell in the second shell, called the 2s subshell.

Slide 30: Beryllium

Beryllium has four electrons, two in the 1s subshell and two in the 2s subshell.

What happens for an element with five electrons?

Slide 31: Boron

Element number five, Boron, has five electrons with two in the 1s subshell and two in the 2s subshell. The fifth electron is located in the second subshell of the second shell, called the 2p subshell.

Slide 32: Carbon

Element six, Carbon, continues the pattern, with six electrons, two in the 1s subshell, two in the 2s subshell, and two in the 2p subshell.

Slide 33: Neon

The 2p subshell can hold a maximum of six electrons and element ten, Neon, is the element with the 2p subshell full.

What happens for sodium with eleven electrons?

Slide 34: Sodium

When the next element has eleven electrons, the last electron is in the first subshell of the third shell, called the 3s subshell.

Slide 35: s block

The s block elements

The first two elements of every period in the periodic table have their outermost electrons in s subshells, so elements in the first two columns of the periodic table are called s block elements.

Slide 36: Magnesium

The twelfth element, Magnesium, is part of the s block, with its outermost two electrons in the 3s subshell.

Slide 37: Aluminum

The next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of the third shell, the 3p subshell.

Slide 38: p block

The p block elements

Similar to how the first two elements of each period had the outermost electron located in an s subshell, the last six elements of each period have the outermost electrons located in a p subshell. These elements are called the p block elements and many properties of these elements are explained using p subshells.

Slide 39: Potassium & Calcium

The first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.

Slide 40: Scandium

The next element, Scandium, has its next electron added to the outermost subshell—but this subshell is part of the third shell. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells. Scandium has two electrons in the 4s subshell, following the pattern of the two elements before it, but it has one electron in the third subshell of the third shell, called the 3d subshell.

Slide 41: Titanium

The next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d.

Slide 42: 3d subshell & Zinc

This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.

Slide 43: Periodic table, period 4 highlighted

Linking the electron arrangement to the Periodic Table

This pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.

Slide 44: Periodic table, period 5 highlighted

The pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.

What is the name for the group of elements in the middle of the periodic table?

Slide 45: d block

The d block elements

The group of elements in the middle ten columns of the periodic table are called the d block because these elements have between one and ten electrons in the d subshell.

Slide 46: f subshells

Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to the d subshells and the f subshells of inner shells.

Slide 47: periodic table and f subshells (all shaded at bottom)

This pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. The periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons.

Slide 48: Sixth period: s subshell

Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.

Slide 49: Sixth period: f subshell

Before filling the 5d subshell, the 4f subshell is filled for the next fourteen elements, Lanthanum to Ytterbium.

Slide 50: Sixth period: d subshell

Then the next ten elements fill the 5d subshell and

Slide 51: Sixth period: p subshell

The last six elements fill the 6p subshell.

What is the order of the subshells for the seventh period like?

Slide 52: Seventh period

The elements in period seven follow the same pattern as those in period six.

Slide 53: f block (middle)

The f block elements

Even though these elements that fill the f subshells would ideally be located in the middle left of the periodic table,

Slide 54: f block (bottom)

they are usually placed at the bottom of most periodic tables. They are called the f block elements. They are also often called the Lanthanides and Actinides after the elements that begin each row.

Slide 55: Shells and subshells (empty)

Electron configurations

Drawing diagrams for the electronic structure of atoms can be represented with a written shorthand notation called electron configuration. The electron configuration represents the shells and subshells that have electrons with letter and number combinations: 1s, 2s, 2p, 3s, 3p and so on. After each letter, a superscript number indicates how many electrons are located in that subshell. The pattern for electron configurations is the most straightforward for the first 18 elements.

Slide 56: H

Hydrogen has a configuration of $1s^1$ because it has one electron in the s subshell in the first shell.

Slide 57: He

Helium has a configuration of $1s^2$ because it has two electrons in the s subshell in the first shell.

What is the configuration for an element with three electrons?

Slide 58: Li

There is no 1p subshell, so Lithium has a configuration of $1s^22s^1$ because it has two electrons in the s subshell in the first shell and one electron in the s subshell of the second shell.

Slide 59: Be

Beryllium continues the pattern with $1s^22s^2$.

Slide 60: B

Since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^22s^22p^1$ with two electrons in the s subshell in the first shell, two electrons in the s subshell of the second shell and one electron in the p subshell of the second shell.

Slide 61: up to Ne

Continuing across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^22s^22p^6$.

What is the configuration for sodium with eleven electrons?

Slide 62: Na & third period

The third period begins with sodium, with configuration $1s^22s^22p^63s^1$ for its eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.

Slide 63: K & Ca

Configuration changes in the fourth period

For the fourth period, the pattern changes with the d block elements. The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.

Slide 64: Sc and d block

With scandium and the other d block elements, the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.

Slide 65: d1 to d10

The general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.

Slide 66: P table and La

The other d block elements follow the same general pattern as those in the fourth period do, but another pattern layer is added for the f block elements, beginning with Lanthanum in period 6.

Slide 67: Atomic sizes

Electron arrangement and atomic size

The arrangement of electrons into shells and subshells is used to explain patterns in the sizes of the atoms for different elements.

Atomic size decreases in element families from the largest at the bottom of the periodic table to the smallest at the top, and atomic size also decreases going across the periods of the table from left to right.

Slide 68: Shells comparison

The electronic structure explanation for the first pattern in atomic size is that an element located below another element on the periodic table has more shells of electrons around and has a larger size.

Are elements in the third period larger or smaller than the elements above them?

Slide 69: Periods comparison

For the second pattern, the explanation from electronic structure is that while elements to the right side of the periodic table have more electrons than elements to the left do, the electrons are in the same shell of the atom.

Slide 70: More protons

Because the elements to the right side also have more protons, the electrons in the outermost shell feel a stronger attractive force from the nucleus and are therefore closer to the nucleus, making the atoms of those elements smaller.

Are the elements at the far right of the periodic table larger or smaller than the elements to their left?

Slide 71: Blank Periodic Table

Element groups and electronic structure

The elements were originally grouped in the periodic table based on their properties.

The model of electronic structure is used to explain these properties.

Slide 72: Valence electrons

The cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of the atom and which are involved in chemical reactions.

Slide 73: Alkali metals, 1 valence e⁻

Groups of elements, valence electrons, and common ionic charges

The first group of elements in the periodic table is the alkali metals, all of which have one valence electron in the outermost shell. That electron is always located in the s subshell of the outermost shell and the alkali elements are described as being s¹ elements. Removal of the one valence electron leads to these elements forming cations with +1 charge.

Slide 74: Alkaline earth metals, 2 valence e⁻

The second group of elements in the periodic table is the alkaline earth metals, each of which has two valence electrons. These elements are described as s² elements and they all form cations with +2 charges, corresponding to the removal of the two valence electrons.

Slide 75: Group 3A elements, 3 valence e⁻

For the elements in group 3A of the periodic table, there are three electrons in the valence shell and these elements mostly form cations with +3 charges.

Because only two electrons can be in the s subshell, these elements have a third electron in a p subshell and have s²p¹ configurations.

Do elements that lose electrons become positively or negatively charged?

Slide 76: Blank Periodic Table

The elements on the right side of the periodic table also form ions with similar charges when they gain electrons.

Slide 77: Halogens, 7 valence e⁻ (one empty spot)

The halogens in group 7A of the periodic table have seven valence electrons in s²p⁵ configurations. The halogens all commonly form anions with one more electron, giving them -1 charges. Atomic theory states that halogens have an

unoccupied space in their valence electron shell and enough attraction from their nuclei to attract and keep an extra electron in the valence shell, forming an anion.

Slide 78: Chalcogens, 6 valence e⁻ (two empty spots)

The elements in group 6A commonly form anions with two more electrons, giving them -2 charges. This charge parallels the fact that these elements have s²p⁴ configurations with room for two additional electrons in the outermost p subshell.

Slide 79: Pnictogens, 5 valence e⁻ (three empty spots)

The elements in group 5A commonly form anions with three more electrons, giving them -3 charges. This charge parallels the fact that these elements have s²p³ configurations with room for three additional electrons in the outermost p subshell.

Do elements that gain electrons become positively or negatively charged?

Slide 80: Group 4A elements, 4 valence e⁻ (four empty spots)

The elements in group 4A have a more complicated pattern. When these elements form anions with four more electrons, they have -4 charges. This charge parallels the fact that these elements have s²p² configurations with room for four additional electrons in the outermost p subshell. But some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.

Slide 81: Noble gases

On the far right of the periodic table are the noble gases, with full valence shells holding 2 s and 6 p electrons. These elements do not normally form ions or ionic compounds because it is energetically unfavorable for them to add an additional electron to a new valence shell with all of its current electrons partially counteracting the attractive force of the nucleus. This counteraction is called electron shielding in technical chemistry language.

How is an element's group related to the number of valence electrons in that element's atoms?

Slide 82: Summary: P-table and Atomic Model

Conclusion

Atomic sizes and common ionic charges are two of many properties of atoms that can be explained using atomic models of electron configurations with shells and subshells. These properties and the model of the atom parallel the organization and structure of the periodic table. The model of the atom and structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to remove electrons from atoms. The periodic table and the atomic model can be used to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.

Atomic Structure Script: Personification (He)

Slide 1: Title Slide

Welcome to an instructional video on Atomic Structure

Slide 2: Introduction

Introduction to Atoms

Atoms are the smallest unit of matter that can still be an element. A particle that is smaller than an atom is no longer an element, but he is called an elementary particle or a subatomic particle.

An atom is therefore also the smallest unit of an element and he consists of electrons and a nucleus with neutrons and protons. The study of chemistry is primarily concerned with his electrons.

Slide 3: Periodic table

The Periodic Table

The number of electrons is different for each element, but each element on the periodic table is arranged in order from the element whose atoms contain only one electron (hydrogen) to the element whose atoms contain 118 electrons (ununoctium). All those elements are in order following from left to right for each row, following the rows from top to bottom.

Models of the electronic structure of atoms are used to explain the chemical properties of elements through descriptions of how the electrons are arranged around the nucleus.

Slide 4: Shells

Shells and subshells

The model of electronic structure begins with electrons divided into primary groupings called shells. Those shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within each shell, electrons are grouped into subshells.

Slide 5: Subshells

The number of subshells varies for each shell, but follows a pattern. The number of subshells is equal to the number of each shell.

Slide 6:

The first shell, he has one subshell

Slide 7:

while the second shell, he has two subshells,

Slide 8:

the third shell, he has three subshells,

Slide 9:

and so on.

How many shells does the fourth shell have? The fifth shell?

Subshells don't have numbers, but instead they have letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.

Slide 10: s subshells

The first subshell in every shell of electrons is the s subshell. His letter S stands for sharp.

Slide 11: p subshells

The second subshell, which is found in every electron shell except for the first shell is the p subshell. His letter P stands for principle.

Slide 12: d subshells

The third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. His letter D stands for diffuse.

Slide 13: f subshells

The fourth subshell, found in the fourth shell and beyond, is the f subshell. His letter F stands for fine.

Slide 14: s, p, d, f, g, h, i...

After the f subshell, there are more subshells in the larger shells, but the letters for those guys are g, h, i, and so on, following the alphabet. Their letters are not related to any names used by early chemists.

Slide 15: Shells only

Electrons and shells

There are a limited number of electrons that can be in each shell in the atomic model.

Only two electrons can fit in the first shell.

Slide 16: Hydrogen

The first element, Hydrogen, has one electron and he is located in the first shell.

Slide 17: Helium

The second element, Helium, has two electrons and they are located in the first shell.

What happens for an element with three electrons?

Slide 18: Lithium

The third element, Lithium, has three electrons, more than the maximum for the first shell, so two of them are in the first shell and one of them in the second shell.

Slide 19: Periodic table period change

This change to the second shell is paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.

Slide 20: Beryllium

The fourth element, Beryllium, has four electrons, two of them in the first shell and two of them in the second shell.

The second shell can hold a maximum of eight electrons, so the elements in period two use the second shell up to the tenth element,

Slide 21: Neon

Neon, he has ten electrons, two electrons in the first shell and eight electrons in the second shell.

What happens for an element with eleven electrons?

Slide 22: Sodium

The eleventh element, sodium, he has more electrons than his first and second shells can hold and has his eleventh electron in the third shell.

Slide 23: Periodic table period change

The change from the second electron shell to the third electron shell is paralleled in the periodic table by a shift from the second period to the third period.

Slide 24: Argon

The pattern of electrons being added for the third period follows the same pattern as the second period up to element 18, Argon.

Argon is not the last element to add electrons to the third shell even though he is the last element in period three.

Slide 25: Periodic table

This is because the periodic table matches a second pattern of the atomic model where the fourth period of the table represents parts of his third and fourth shells of electrons. The second pattern of the atomic model is his pattern for his subshells .

Slide 26: Generic subshells with electrons

Electrons in the subshells

Each atom has a limited number of electrons in each of his shells and also in each of his subshells.

Atoms fill their shells in numerical order with their electrons. They also fill their subshells within each shell with electrons in the order s, p, d, f, g, and so on.

Slide 27: Hydrogen

Hydrogen has his one electron in his first subshell in his first shell, called his 1s subshell.

Slide 28: Helium

Helium has his two electrons in his first subshell in his first shell, called his 1s subshell.

Slide 29: Lithium

Lithium has three electrons, two in his 1s subshell and one in the first subshell in his second shell, called the 2s subshell.

Slide 30: Beryllium

Beryllium has four electrons, two in his 1s subshell and two in his 2s subshell. What happens for an element with five electrons?

Slide 31: Boron

Element number five, Boron, he has five electrons with two in his 1s subshell and two in his 2s subshell. His fifth electron is located in the second subshell of his second shell, called the 2p subshell.

Slide 32: Carbon

Element six, Carbon, continues the pattern, with six electrons, two in his 1s subshell, two in his 2s subshell, and two in his 2p subshell.

Slide 33: Neon

The 2p subshell can hold a maximum of six electrons and element ten, Neon, is the element with his 2p subshell full.

What happens for sodium with his eleven electrons?

Slide 34: Sodium

When the next element has eleven electrons, his last electron is in the first subshell of his third shell, called the 3s subshell.

Slide 35: s block

The s block elements

Because each of the first two elements of every period in the periodic table has his outermost electrons in s subshells, all these elements in the first two columns of the periodic table are called s block elements.

Slide 36: Magnesium

The twelfth element, Magnesium, is part of the s block, with his outermost two electrons in the 3s subshell.

Slide 37: Aluminum

The next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of his third shell, the 3p subshell.

Slide 38: p block

The p block elements

Similar to how each of the first two elements of each period had his outermost electrons located in an s subshell, each of the last six elements of each period has his outermost electrons located in a p subshell. These elements are called the p block elements and many properties of these elements are explained using p subshells.

Slide 39: Potassium & Calcium

The first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.

Slide 40: Scandium

The next element, Scandium, has his next electron added the outermost subshell—but this subshell is part of his third shell. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells. Scandium has two electrons in the 4s subshell, following the pattern of the two elements before him, but he has one electron in the third subshell of his third shell, called the 3d subshell.

Slide 41: Titanium

The next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d.

Slide 42: 3d subshell & Zinc

This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.

Slide 43: Periodic table, period 4 highlighted

Linking the electron arrangement to the Periodic Table

This pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.

Slide 44: Periodic table, period 5 highlighted

The pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.

What is the name for the group of elements in the middle of the periodic table?

Slide 45: d block

The d block elements

The group of elements in the middle ten columns of the periodic table are called the d block because each of these elements has between one and ten electrons in his d subshell.

Slide 46: f subshells

Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to their d subshells and the f subshells of their inner shells.

Slide 47: periodic table and f subshells (all shaded at bottom)

This pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. The periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons.

Slide 48: Sixth period: s subshell

Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.

Slide 49: Sixth period: f subshell

Before filling the 5d subshell, the next fourteen elements, Lanthanum to Ytterbium, fill their 4f subshells.

Slide 50: Sixth period: d subshell

Then the next ten elements fill their 5d subshell and

Slide 51: Sixth period: p subshell

The last six elements fill their 6p subshell.

What is the order of the subshells for the seventh period like?

Slide 52: Seventh period

The elements in period seven follow the same pattern as those in period six.

Slide 53: f block (middle)

The f block elements

Even though these elements that fill their f subshells would ideally be located in the middle left of the periodic table,

Slide 54: f block (bottom)

they are usually placed at the bottom of most periodic tables. They are called the f block elements. They are also often called the Lanthanides and Actinides after the elements that begin each row.

Slide 55: Shells and subshells (empty)

Electron configurations

Drawing diagrams for the electronic structure of atoms can be represented with a written shorthand notation called electron configuration. The electron configuration represents the shells and subshells that have electrons with letter and number combinations: 1s, 2s, 2p, 3s, 3p and so on. After each letter, a superscript number indicates how many electrons are located in that subshell. The pattern for electron configurations is the most straightforward for the first 18 elements.

Slide 56: H

Hydrogen has a configuration of $1s^1$ because he has one electron in the s subshell in his first shell.

Slide 57: He

Helium has a configuration of $1s^2$ because he has two electrons in the s subshell in his first shell.

What is the configuration for an element who has three electrons?

Slide 58: Li

There is no 1p subshell, so Lithium has a configuration of $1s^22s^1$ because he has two electrons in the s subshell in his first shell and one electron in the s subshell of his second shell.

Slide 59: Be

Beryllium continues the pattern with $1s^22s^2$.

Slide 60: B

Since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^22s^22p^1$ with two electrons in the s subshell in his first shell, two electrons in the s subshell of his second shell and one electron in the p subshell of his second shell.

Slide 61: up to Ne

Continuing across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^22s^22p^6$.

What is the configuration for sodium with his eleven electrons?

Slide 62: Na & third period

The third period begins with sodium, with configuration $1s^22s^22p^63s^1$ for his eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.

Slide 63: K & Ca

Configuration changes in the fourth period

For the fourth period, the pattern changes with the d block elements. The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.

Slide 64: Sc and d block

With scandium and the other d block elements, the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.

Slide 65: d1 to d10

The general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.

Slide 66: P table and La

The other d block elements follow the same general pattern as those in the fourth period do, but another pattern layer is added for the f block elements, beginning with Lanthanum in period 6.

Slide 67: Atomic sizes

Electron arrangement and atomic size

The arrangement of electrons into shells and subshells is used to explain patterns in the sizes of the atoms for different elements.

Atomic size decreases in element families from the largest at the bottom of the periodic table to the smallest at the top, and atomic size also decreases going across the periods of the table from left to right.

Slide 68: Shells comparison

The electronic structure explanation for the first pattern in atomic size is that if an element is located below another element on the periodic table, then he has more shells of electrons around and he is larger.

Is an element in the third period larger or smaller than the element above him?

Slide 69: Periods comparison

For the second pattern, the explanation from electronic structure is that an element to the right side of the periodic table has more electrons than elements to his left do, both he and the elements to the left have electrons are in the same shell of the atom.

Slide 70: More protons

Because an element to the right side also has more protons, the electrons in his outermost shell feel a stronger attractive force from his nucleus and are therefore closer to the nucleus, making him smaller.

Is an element at the far right of the periodic table larger or smaller than the element to his left?

Slide 71: Blank Periodic Table

Element groups and electronic structure

The elements were originally grouped in the periodic table based on their properties.

The model of electronic structure is used to explain their properties.

Slide 72: Valence electrons

The cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of an atom and which are involved in his chemical reactions.

Slide 73: Alkali metals, 1 valence e⁻

Groups of elements, valence electrons, and common ionic charges

The first group of elements in the periodic table is the alkali metals, each of which has one valence electron in his outermost shell. That electron is always located in the s subshell of his outermost shell and each alkali element is described as an s¹ element. Removal of his one valence electron leads to the element forming a cation with +1 charge.

Slide 74: Alkaline earth metals, 2 valence e⁻

The second group of elements in the periodic table is the alkaline earth metals, each of which has two valence electrons. Each of these elements is described as an s² element and each forms a cation with a +2 charge, corresponding to the removal of his two valence electrons.

Slide 75: Group 3A elements, 3 valence e⁻

For each element in group 3A of the periodic table, there are three electrons in his valence shell and he forms a cation with a +3 charge. Because only two electrons can be in his s subshell, he has a third electron in a p subshell and has an s²p¹ configuration.

Does an element that loses some of his electrons become positively or negatively charged?

Slide 76: Blank Periodic Table

The elements on the right side of the periodic table also form ions with similar charges when they gain electrons.

Slide 77: Halogens, 7 valence e⁻ (one empty spot)

Each of the halogens in group 7A of the periodic table has seven valence electrons in an s²p⁵ configuration. Each halogen commonly forms an anion with

one more electron, giving him a -1 charge. Atomic theory states that he has an unoccupied space in his valence electron shell and enough attraction from his nucleus to attract and keep an extra electron in his valence shell, making him into an anion.

Slide 78: Chalcogens, 6 valence e⁻ (two empty spots)

Each of the elements in group 6A commonly forms an anion with two more electrons, giving him a -2 charge. This charge parallels the fact that he has an s²p⁴ configuration with room for two additional electrons in his outermost p subshell.

Slide 79: Pnictogens, 5 valence e⁻ (three empty spots)

Each of the elements in group 5A commonly forms an anion with three more electrons, giving him a -3 charge. This charge parallels the fact that he has an s²p³ configuration with room for three additional electrons in his outermost p subshell.

Does an element that gains electrons become positively or negatively charged?

Slide 80: Group 4A elements, 4 valence e⁻ (four empty spots)

The elements in group 4A have a more complicated pattern. When one of these elements forms an anion with four more electrons, he has a -4 charge. This charge parallels the fact that he has an s²p² configuration with room for four additional electrons in his outermost p subshell. But some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.

Slide 81: Noble gases

On the far right of the periodic table are the noble gases, with full valence shells holding 2 s and 6 p electrons. These elements do not normally form ions or ionic compounds because it is energetically unfavorable for any of them to add an additional electron to a new valence shell when all of his current electrons partially counteract the attractive force of his nucleus. This counteraction is called electron shielding in technical chemistry language.

How is an element's group related to the number of valence electrons in his atoms?

Slide 82: Summary: P-table and Atomic Model

Conclusion

Atomic sizes and common ionic charges are two of many properties of atoms that can be explained using atomic models of electron configurations with shells and subshells. These properties and the model of the atom parallel the organization and structure of the periodic table. The model of the atom and structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to removed electrons from atoms. The periodic table and the atomic model can be used to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.

Atomic Structure Script: Female Personification (She)

Slide 1: Title Slide

Welcome to an instructional video on Atomic Structure

Slide 2: Introduction

Introduction to Atoms

Atoms are the smallest unit of matter that can still be considered an element. A particle that is smaller than an atom is no longer elements, but she is called an elementary particle or a subatomic particle.

An atom is therefore also the smallest unit of an element and she consists of electrons and a nucleus with neutrons and protons. The study of chemistry is primarily concerned with her electrons.

Slide 3: Periodic table

The Periodic Table

The number of electrons is different for each element, but each element on the periodic table is arranged in order from the element whose atoms contain only one electron (hydrogen) to the element whose atoms contain 118 electrons (ununoctium). All those elements are in order following from left to right for each row, following the rows from top to bottom.

Models of the electronic structure of atoms are used to explain the chemical properties of elements through descriptions of how the electrons are arranged around the nucleus.

Slide 4: Shells

Shells and subshells

The model of electronic structure begins with electrons divided into primary groupings called shells. Those shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within each shell, electrons are grouped into subshells.

Slide 5: Subshells

The number of subshells varies for each shell, but follows a pattern. The number of subshells is equal to the number of each shell.

Slide 6:

The first shell, she has one subshell

Slide 7:

while the second shell, she has two subshells,

Slide 8:

the third shell, she has three subshells,

Slide 9:

and so on.

How many shells does the fourth shell have? The fifth shell?

Subshells don't have numbers, but instead they have letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.

Slide 10: s subshells

The first subshell in every shell of electrons is the s subshell. Her letter S stands for sharp.

Slide 11: p subshells

The second subshell, which is found in every electron shell except for the first shell is the p subshell. Her letter P stands for principle.

Slide 12: d subshells

The third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. Her letter D stands for diffuse.

Slide 13: f subshells

The fourth subshell, found in the fourth shell and beyond, is the f subshell. Her letter F stands for fine.

Slide 14: s, p, d, f, g, h, i...

After the f subshell, there are more subshells in the larger shells, but the letters for those subshells are g, h, i, and so on, following the alphabet. Their letters are not related to any names used by early chemists.

Slide 15: Shells only

Electrons and shells

There are a limited number of electrons that can be in each shell in the atomic model.

Only two electrons can fit in the first shell.

Slide 16: Hydrogen

The first element, Hydrogen, has one electron and she is located in the first shell.

Slide 17: Helium

The second element, Helium, has two electrons and they are located in the first shell.

What happens for an element with three electrons?

Slide 18: Lithium

The third element, Lithium, has three electrons, more than the maximum for the first shell, so two of them are in the first shell and one of them in the second shell.

Slide 19: Periodic table period change

This change to the second shell is paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.

Slide 20: Beryllium

The fourth element, Beryllium, has four electrons, two of them in the first shell and two of them in the second shell.

The second shell can hold a maximum of eight electrons, so the elements in period two use the second shell up to the tenth element,

Slide 21: Neon

Neon, she has ten electrons, two electrons in the first shell and eight electrons in the second shell.

What happens for an element with eleven electrons?

Slide 22: Sodium

The eleventh element, sodium, she has more electrons than her first and second shells can hold and has her eleventh electron in the third shell.

Slide 23: Periodic table period change

The change from the second electron shell to the third electron shell is paralleled in the periodic table by a shift from the second period to the third period.

Slide 24: Argon

The pattern of electrons being added for the third period follows the same pattern as the second period up to element 18, Argon.

Argon is not the last element to add electrons to the third shell even though she is the last element in period three.

Slide 25: Periodic table

This is because the periodic table matches a second pattern of the atomic model where the fourth period of the table represents parts of her third and fourth shells of electrons. The second pattern of the atomic model is her pattern for her subshells.

Slide 26: Generic subshells with electrons

Electrons in the subshells

Each atom has a limited number of electrons in each of her shells and also in each of her subshells.

Atoms fill their shells in numerical order with their electrons. They also fill their subshells within each shell with electrons in the order s, p, d, f, g, and so on.

Slide 27: Hydrogen

Hydrogen has her one electron in her first subshell in her first shell, called her 1s subshell.

Slide 28: Helium

Helium has her two electrons in her first subshell in her first shell, called her 1s subshell.

Slide 29: Lithium

Lithium has three electrons, two in her 1s subshell and one in the first subshell in her second shell, called the 2s subshell.

Slide 30: Beryllium

Beryllium has four electrons, two in her 1s subshell and two in her 2s subshell. What happens for an element with five electrons?

Slide 31: Boron

Element number five, Boron, she has five electrons with two in her 1s subshell and two in her 2s subshell. Her fifth electron is located in the second subshell of her second shell, called the 2p subshell.

Slide 32: Carbon

Element six, Carbon, continues the pattern, with six electrons, two in her 1s subshell, two in her 2s subshell, and two in her 2p subshell.

Slide 33: Neon

The 2p subshell can hold a maximum of six electrons and element ten, Neon, is the element with her 2p subshell full.

What happens for sodium with her eleven electrons?

Slide 34: Sodium

When the next element has eleven electrons, her last electron is in the first subshell of her third shell, called the 3s subshell.

Slide 35: s block

The s block elements

Because each of the first two elements of every period in the periodic table has her outermost electrons in s subshells, all these elements in the first two columns of the periodic table are called s block elements.

Slide 36: Magnesium

The twelfth element, Magnesium, is part of the s block, with her outermost two electrons in the 3s subshell.

Slide 37: Aluminum

The next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of her third shell, the 3p subshell.

Slide 38: p block

The p block elements

Similar to how each of the first two elements of each period had her outermost electrons located in an s subshell, each of the last six elements of each period has her outermost electrons located in a p subshell. These elements are called the p block elements and many properties of these elements are explained using p subshells.

Slide 39: Potassium & Calcium

The first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.

Slide 40: Scandium

The next element, Scandium, has her next electron added the outermost subshell—but this subshell is part of her third shell. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells. Scandium has two electrons in the 4s subshell, following the pattern of the two elements before her, but she has one electron in the third subshell of her third shell, called the 3d subshell.

Slide 41: Titanium

The next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d.

Slide 42: 3d subshell & Zinc

This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.

Slide 43: Periodic table, period 4 highlighted

Linking the electron arrangement to the Periodic Table

This pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.

Slide 44: Periodic table, period 5 highlighted

The pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.

What is the name for the group of elements in the middle of the periodic table?

Slide 45: d block

The d block elements

The group of elements in the middle ten columns of the periodic table are called the d block because each of these elements has between one and ten electrons in her d subshell.

Slide 46: f subshells

Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to their d subshells and the f subshells of their inner shells.

Slide 47: periodic table and f subshells (all shaded at bottom)

This pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. The periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons.

Slide 48: Sixth period: s subshell

Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.

Slide 49: Sixth period: f subshell

Before filling the 5d subshell, the next fourteen elements, Lanthanum to Ytterbium, fill their 4f subshells.

Slide 50: Sixth period: d subshell

Then the next ten elements fill their 5d subshell and

Slide 51: Sixth period: p subshell

The last six elements fill their 6p subshell.

What is the order of the subshells for the seventh period like?

Slide 52: Seventh period

The elements in period seven follow the same pattern as those in period six.

Slide 53: f block (middle)

The f block elements

Even though these elements that fill their f subshells would ideally be located in the middle left of the periodic table,

Slide 54: f block (bottom)

they are usually placed at the bottom of most periodic tables. They are called the f block elements. They are also often called the Lanthanides and Actinides after the elements that begin each row.

Slide 55: Shells and subshells (empty)

Electron configurations

Drawing diagrams for the electronic structure of atoms can be represented with a written shorthand notation called electron configuration. The electron configuration represents the shells and subshells that have electrons with letter and number combinations: 1s, 2s, 2p, 3s, 3p and so on. After each letter, a superscript number indicates how many electrons are located in that subshell. The pattern for electron configurations is the most straightforward for the first 18 elements.

Slide 56: H

Hydrogen has a configuration of $1s^1$ because she has one electron in the s subshell in her first shell.

Slide 57: He

Helium has a configuration of $1s^2$ because she has two electrons in the s subshell in her first shell.

What is the configuration for an element who has three electrons?

Slide 58: Li

There is no 1p subshell, so Lithium has a configuration of $1s^22s^1$ because she has two electrons in the s subshell in her first shell and one electron in the s subshell of her second shell.

Slide 59: Be

Beryllium continues the pattern with $1s^22s^2$.

Slide 60: B

Since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^22s^22p^1$ with two electrons in the s subshell in her first shell, two electrons in the s subshell of her second shell and one electron in the p subshell of her second shell.

Slide 61: up to Ne

Continuing across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^22s^22p^6$.

What is the configuration for sodium with her eleven electrons?

Slide 62: Na & third period

The third period begins with sodium, with configuration $1s^22s^22p^63s^1$ for her eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.

Slide 63: K & Ca

Configuration changes in the fourth period

For the fourth period, the pattern changes with the d block elements. The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.

Slide 64: Sc and d block

With scandium and the other d block elements, the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.

Slide 65: d1 to d10

The general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.

Slide 66: P table and La

The other d block elements follow the same general pattern as those in the fourth period do, but another pattern layer is added for the f block elements, beginning with Lanthanum in period 6.

Slide 67: Atomic sizes

Electron arrangement and atomic size

The arrangement of electrons into shells and subshells is used to explain patterns in the sizes of the atoms for different elements.

Atomic size decreases in element families from the largest at the bottom of the periodic table to the smallest at the top, and atomic size also decreases going across the periods of the table from left to right.

Slide 68: Shells comparison

The electronic structure explanation for the first pattern in atomic size is that if an element is located below another element on the periodic table, then she has more shells of electrons around and she is larger.

Is an element in the third period larger or smaller than the element above her?

Slide 69: Periods comparison

For the second pattern, the explanation from electronic structure is that an element to the right side of the periodic table has more electrons than elements to her left do, both she and the elements to the left have electrons are in the same shell of the atom.

Slide 70: More protons

Because an element to the right side also has more protons, the electrons in her outermost shell feel a stronger attractive force from her nucleus and are therefore closer to the nucleus, making her smaller.

Is an element at the far right of the periodic table larger or smaller than the element to her left?

Slide 71: Blank Periodic Table

Element groups and electronic structure

The elements were originally grouped in the periodic table based on their properties.

The model of electronic structure is used to explain their properties.

Slide 72: Valence electrons

The cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of an atom and which are involved in her chemical reactions.

Slide 73: Alkali metals, 1 valence e⁻

Groups of elements, valence electrons, and common ionic charges

The first group of elements in the periodic table is the alkali metals, each of which has one valence electron in her outermost shell. That electron is always located in the s subshell of her outermost shell and each alkali element is described as an s¹ element. Removal of her one valence electron leads to the element forming a cation with +1 charge.

Slide 74: Alkaline earth metals, 2 valence e⁻

The second group of elements in the periodic table is the alkaline earth metals, each of which has two valence electrons. Each of these elements is described as an s² element and each forms a cation with a +2 charge, corresponding to the removal of her two valence electrons.

Slide 75: Group 3A elements, 3 valence e⁻

For each element in group 3A of the periodic table, there are three electrons in her valence shell and she forms a cation with a +3 charge. Because only two electrons can be in her s subshell, she has a third electron in a p subshell and has an s²p¹ configuration.

Does an element that loses some of her electrons become positively or negatively charged?

Slide 76: Blank Periodic Table

The elements on the right side of the periodic table also form ions with similar charges when they gain electrons.

Slide 77: Halogens, 7 valence e⁻ (one empty spot)

Each of the halogens in group 7A of the periodic table has seven valence electrons in an s²p⁵ configuration. Each halogen commonly forms an anion with

one more electron, giving her a -1 charge. Atomic theory states that she has an unoccupied space in her valence electron shell and enough attraction from her nucleus to attract and keep an extra electron in her valence shell, making her into an anion.

Slide 78: Chalcogens, 6 valence e⁻ (two empty spots)

Each of the elements in group 6A commonly forms an anion with two more electrons, giving her a -2 charge. This charge parallels the fact that she has an s²p⁴ configuration with room for two additional electrons in her outermost p subshell.

Slide 79: Pnictogens, 5 valence e⁻ (three empty spots)

Each of the elements in group 5A commonly forms an anion with three more electrons, giving her a -3 charge. This charge parallels the fact that she has an s²p³ configuration with room for three additional electrons in her outermost p subshell.

Does an element that gains electrons become positively or negatively charged?

Slide 80: Group 4A elements, 4 valence e⁻ (four empty spots)

The elements in group 4A have a more complicated pattern. When one of these elements forms an anion with four more electrons, she has a -4 charge. This charge parallels the fact that she has an s²p² configuration with room for four additional electrons in her outermost p subshell. But some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.

Slide 81: Noble gases

On the far right of the periodic table are the noble gases, with full valence shells holding 2 s and 6 p electrons. These elements do not normally form ions or ionic compounds because it is energetically unfavorable for any of them to add an additional electron to a new valence shell when all of her current electrons partially counteract the attractive force of her nucleus. This counteraction is called electron shielding in technical chemistry language.

How is an element's group related to the number of valence electrons in her atoms?

Slide 82: Summary: P-table and Atomic Model

Conclusion

Atomic sizes and common ionic charges are two of many properties of atoms that can be explained using atomic models of electron configurations with shells and subshells. These properties and the model of the atom parallel the organization and structure of the periodic table. The model of the atom and structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to removed electrons from atoms. The periodic table and the atomic model can be used to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.

Atomic Structure Script: Personalization (You)

Slide 1: Title Slide

Welcome to an instructional video on Atomic Structure

Slide 2: Introduction

Introduction to Atoms

Atoms are the smallest unit of matter that you can still consider an element. You can't call particles that are smaller than atoms elements, but instead you call them elementary particles or subatomic particles.

Atoms are therefore also the smallest units of the elements.

If you could see an atom, you would see that it consists of electrons and a nucleus with neutrons and protons. When you study chemistry, you are primarily concerned with the electrons.

Slide 3: Periodic table

The Periodic Table

When you study them, you find that the number of electrons is different for each element and that the elements on the periodic table are arranged in order from the element with atoms containing only one electron (hydrogen) to the element with atoms that contain 118 electrons (ununoctium). You can also see that all the elements are in order following from left to right for each row, following the rows from top to bottom.

You can use models of the electronic structure of atoms to explain the chemical properties of elements when you describe how the electrons are arranged around the nucleus.

Slide 4: Shells

Shells and subshells

Your model of electronic structure begins with electrons divided into primary groupings called shells. The shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within the shells, you see electrons grouped into subshells.

Slide 5: Subshells

The number of subshells varies for each shell, but follows a pattern that you can follow. Part of your pattern is that the number of subshells is equal to the number of each shell.

Slide 6:

Here is your pattern for shells. The first shell has one subshell

Slide 7:

while the second shell has two subshells,

Slide 8:

the third shell has three subshells,

Slide 9:

and so on.

How many shells do you think the fourth shell has? The fifth shell?

Subshells are not numbered, but are instead given letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.

Slide 10: s subshells

Within the shells, you find that the first subshell in every shell of electrons is the s subshell. S stands for sharp.

Slide 11: p subshells

Then you find the second subshell, which is found in every electron shell except for the first shell is the p subshell. P stands for principle.

Slide 12: d subshells

Your third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. D stands for diffuse.

Slide 13: f subshells

The fourth subshell, found in the fourth shell and beyond, is the f subshell. F stands for fine.

Slide 14: s, p, d, f, g, h, i...

After the f subshell, you will find more subshells in the larger shells, but the names of those subshells are g, h, i, and so on, following the alphabet. The letters for these subshells are not related to any names used by early chemists.

Slide 15: Shells only

Electrons and shells

Next you find that there are a limited number of electrons in each shell in the atomic model.

Your atom's first shell can hold a maximum of two electrons.

Slide 16: Hydrogen

The first element, Hydrogen, has one electron located in the first shell.

Slide 17: Helium

The second element, Helium, has two electrons located in the first shell.

What do you think happens for an element with three electrons?

Slide 18: Lithium

The third element, Lithium, has three electrons, more than the maximum for the first shell, so there are two electrons in the first shell and one electron in the second shell.

Slide 19: Periodic table period change

You can see this change to the second shell paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.

Slide 20: Beryllium

Your fourth element, Beryllium, has four electrons, two electrons in the first shell and two electrons in the second shell.

You can see that the second shell can hold a maximum of eight electrons, so the elements in period two use the second shell, up to the tenth element,

Slide 21: Neon

Neon, which has ten electrons, two electrons in the first shell and eight electrons in the second shell.

What do you think happens for an element with eleven electrons?

Slide 22: Sodium

When you examine the eleventh element, sodium, there are more electrons than the first and second shells can hold and the eleventh electron is in the third shell.

Slide 23: Periodic table period change

You can see the change from the second electron shell to the third electron shell paralleled in the periodic table by a shift from the second period to the third period.

Slide 24: Argon

You can also see that the pattern of electrons being added for the third period follows the same pattern as the second period up to element 18, Argon.

Be careful here as Argon is not the last element to add electrons to the third shell even though it is the last element in period three.

Slide 25: Periodic table

You can look and see the periodic table showing a second pattern of the atomic model where the fourth period of the table represents parts of the third and fourth shells of electrons in the atomic model. Your second pattern for the atomic model is the pattern for the subshells .

Slide 26: Generic subshells with electrons

Electrons in the subshells

You can find that there are a limited number of electrons in each shell and also in each subshell in the atomic model.

Electrons fill the shells in numerical order. Electrons fill the subshells within each shell in the order s, p, d, f, g, and so on.

Slide 27: Hydrogen

If you could see the atom, you would see that Hydrogen has one electron in the first subshell in the first shell, called the 1s subshell.

Slide 28: Helium

Then you would see that Helium has two electrons in the first subshell in the first shell, called the 1s subshell.

Slide 29: Lithium

But you would find that Lithium has three electrons, two in the 1s subshell and one in the first subshell in the second shell, called the 2s subshell.

Slide 30: Beryllium

Beryllium has four electrons, two in the 1s subshell and two in the 2s subshell.

What do you think happens for an element with five electrons?

Slide 31: Boron

When you get to Element number five, Boron, it has five electrons with two in the 1s subshell and two in the 2s subshell. The fifth electron is located in the second subshell of the second shell, called the 2p subshell.

Slide 32: Carbon

You see that Element six, Carbon, continues the pattern, with six electrons, two in the 1s subshell, two in the 2s subshell, and two in the 2p subshell.

Slide 33: Neon

Eventually you have the 2p subshell holding a maximum of six electrons and element ten, Neon, is the element with the 2p subshell full.

What do you think happens for sodium with eleven electrons?

Slide 34: Sodium

When the next element has eleven electrons, you see the last electron is in the first subshell of the third shell, called the 3s subshell.

Slide 35: s block

The s block elements

Notice that the first two elements of every period in the periodic table have their outermost electrons in s subshells, so elements in the first two columns of the periodic table are called s block elements.

Slide 36: Magnesium

The twelfth element, Magnesium, is part of the s block, with its outermost two electrons in the 3s subshell.

Slide 37: Aluminum

You can see the next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of the third shell, the 3p subshell.

Slide 38: p block

The p block elements

Similar to how the first two elements of each period had the outermost electron located in an s subshell, see that the last six elements of each period have the outermost electrons located in a p subshell. These elements are called the p block elements and you can explain many properties of these elements using p subshells.

Slide 39: Potassium & Calcium

Your first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.

Slide 40: Scandium

But you see the next element, Scandium, has its next electron added the outermost subshell—and this subshell is part of the third shell instead of the fourth. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells.

See that Scandium has two electrons in the 4s subshell, following the pattern of the two elements before it, but it has one electron in the third subshell of the third shell, called the 3d subshell.

Slide 41: Titanium

Notice that the next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d and

Slide 42: 3d subshell & Zinc

This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.

Slide 43: Periodic table, period 4 highlighted

Linking the electron arrangement to the Periodic Table

See how this pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.

Slide 44: Periodic table, period 5 highlighted

You can see how the pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.

What do you think the name is for the group of elements in the middle of the periodic table?

Slide 45: d block

The d block elements

You can call the group of elements in the middle ten columns of the periodic table the d block because these elements have between one and ten electrons in the d subshell.

Slide 46: f subshells

Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to the d subshells and the f subshells of inner shells.

Slide 47: periodic table and f subshells (all shaded at bottom)

You can see how this pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. Also see how the periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons.

Slide 48: Sixth period: s subshell

Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.

Slide 49: Sixth period: f subshell

Notice how before filling the 5d subshell, the 4f subshell is filled for the next fourteen elements, Lanthanum to Ytterbium.

Slide 50: Sixth period: d subshell

Then the next ten elements fill the 5d subshell and

Slide 51: Sixth period: p subshell

The last six elements fill the 6p subshell.

What do you think the order of the subshells for the seventh period is?

Slide 52: Seventh period

The elements in period seven follow the same pattern as those in period six.

Slide 53: f block (middle)

The f block elements

Notice that even though these elements that fill the f subshells would ideally be located in the middle left of the periodic table,

Slide 54: f block (bottom)

they are usually placed at the bottom of most periodic tables. You can call them the f block elements. You can also call them the Lanthanides and Actinides after the elements that begin each row.

Slide 55: Shells and subshells (empty)

Electron configurations

You can replace drawing diagrams for the electronic structure of atoms with a written shorthand notation called electron configuration. Your electron configuration represents the shells and subshells that have electrons with letter and number combinations: 1s, 2s, 2p, 3s, 3p and so on. After each letter, you put a superscript number that indicates how many electrons are located in that subshell.

You will see that the pattern for electron configurations is the most straightforward for the first 18 elements.

Slide 56: H

Hydrogen has a configuration of $1s^1$ because it has one electron in the s subshell in the first shell.

Slide 57: He

Helium has a configuration of $1s^2$ because it has two electrons in the s subshell in the first shell.

What do you think the configuration is for an element with three electrons?

Slide 58: Li

Notice that since there is no 1p subshell, Lithium has a configuration of $1s^2 2s^1$ because it has two electrons in the s subshell in the first shell and one electron in the s subshell of the second shell.

Slide 59: Be

Beryllium continues the pattern with $1s^2 2s^2$.

Slide 60: B

Now you can see that since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^2 2s^2 2p^1$ with two electrons in the s subshell in the first shell, two electrons in the s subshell of the second shell and one electron in the p subshell of the second shell.

Slide 61: up to Ne

When you continue across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^2 2s^2 2p^6$.

What do you think the configuration is for sodium with eleven electrons?

Slide 62: Na & third period

Then when you begin the third period with sodium, there is configuration $1s^2 2s^2 2p^6 3s^1$ for its eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.

Slide 63: K & Ca

Configuration changes in the fourth period

For the fourth period, you will see the pattern changes with the d block elements. The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.

Slide 64: Sc and d block

With scandium and the other d block elements, you see the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.

Slide 65: d1 to d10

You will find the general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.

Slide 66: P table and La

The other d block elements follow the same general pattern as those in the fourth period do, but you find yet another pattern layer is added for the f block elements, beginning with Lanthanum in period 6.

Slide 67: Atomic sizes

Electron arrangement and atomic size

You can use the arrangement of electrons into shells and subshells to explain patterns in the sizes of the atoms for different elements.

Atomic size decreases in element families from the largest at the bottom of the periodic table to the smallest at the top, and atomic size also decreases going across the periods of the table from left to right.

Slide 68: Shells comparison

Your electronic structure explanation for the first pattern in atomic size is that an element located below another element on the periodic table has more shells of electrons around and has a larger size.

Are elements in the third period larger or smaller than the elements above them?

Slide 69: Periods comparison

For your second pattern, you can explain with electronic structure that while elements to the right side of the periodic table have more electrons than elements to the left do, the electrons are in the same shell of the atom and

Slide 70: More protons

Because the elements to the right side also have more protons, the electrons in the outermost shell feel a stronger attractive force from the nucleus and are therefore closer to the nucleus, making the atoms of those elements smaller.

Are the elements at the far right of the periodic table larger or smaller than the elements to their left?

Slide 71: Blank Periodic Table

Element groups and electronic structure

The elements were originally grouped in the periodic table based on their properties.

You can use the model of electronic structure to explain these properties.

Slide 72: Valence electrons

You will find that the cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of the atom and which are involved in chemical reactions.

Slide 73: Alkali metals, 1 valence e⁻

Groups of elements, valence electrons, and common ionic charges

Your first group of elements in the periodic table is the alkali metals, all of which have one valence electron in the outermost shell. That electron is always located in the s subshell of the outermost shell and the alkali elements are described as being s¹ elements. When you remove the one valence electron these elements form cations with +1 charge.

Slide 74: Alkaline earth metals, 2 valence e⁻

Your second group of elements in the periodic table is the alkaline earth metals, each of which has two valence electrons. These elements are described as s² elements and they all form cations with +2 charges when you remove the two valence electrons.

Slide 75: Group 3A elements, 3 valence e⁻

With the elements in group 3A of the periodic table, you find they have three electrons in the valence shell and these elements mostly form cations with +3

charges. Notice that because only two electrons can be in the s subshell, these elements have a third electron in a p subshell and have s^2p^1 configurations. Do elements that lose electrons become positively or negatively charged?

Slide 76: Blank Periodic Table

Your elements on the right side of the periodic table also form ions with similar charges when they gain electrons.

Slide 77: Halogens, 7 valence e^- (one empty spot)

You saw before that the halogens in group 7A of the periodic table have seven valence electrons in s^2p^5 configurations. The halogens all commonly form anions with one more electron, giving them -1 charges. You can explain this with Atomic theory that halogens have an unoccupied space in their valence electron shell and enough attraction from their nuclei to attract and keep an extra electron in the valence shell, forming an anion.

Slide 78: Chalcogens, 6 valence e^- (two empty spots)

Your elements in group 6A commonly form anions with two more electrons, giving them -2 charges. Notice that this charge parallels the fact that these elements have s^2p^4 configurations with room for two additional electrons in the outermost p subshell.

Slide 79: Pnictogens, 5 valence e^- (three empty spots)

Your elements in group 5A commonly form anions with three more electrons, giving them -3 charges. Notice that this charge parallels the fact that these elements have s^2p^3 configurations with room for three additional electrons in the outermost p subshell.

Do elements that gain electrons become positively or negatively charged?

Slide 80: Group 4A elements, 4 valence e^- (four empty spots)

Your elements in group 4A have a more complicated pattern. When these elements form anions with four more electrons, they have -4 charges. Notice that this charge parallels the fact that these elements have s^2p^2 configurations with room for four additional electrons in the outermost p subshell. But also be aware that some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.

Slide 81: Noble gases

On the far right of the periodic table you have the noble gases, with full valence shells holding 2 s and 6 p electrons. You may know that these elements do not normally form ions or ionic compounds because it is energetically unfavorable for them to add an additional electron to a new valence shell with all of its current electrons partially counteracting the attractive force of the nucleus. You can call this counteraction electron shielding in technical chemistry language. How is an element's group related to the number of valence electrons in that element's atoms?

Slide 82: Summary: P-table and Atomic Model

Conclusion

Atomic sizes and common ionic charges are two of many properties of atoms that you can explain using atomic models of electron configurations with shells and subshells. You have seen how these properties and the model of the atom parallel the organization and structure of the periodic table. The model of the

atom you now know and the structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to remove electrons from atoms. You can use the periodic table and the atomic model to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.

Atomic Structure Script 2: Combination Personalization (You) and Male Personification (He)

Slide 1: Title Slide

Welcome to an instructional video on Atomic Structure

Slide 2: Introduction

Introduction to Atoms

Atoms are the smallest unit of matter that you can still consider an element. You can't call a particle that is smaller than an atom an element, but instead you would call it an elementary particle or a subatomic particle.

Atoms are therefore also the smallest units of the elements.

If you could see an atom, you would see that it consists of electrons and a nucleus with neutrons and protons. When you study chemistry, you are primarily concerned with its electrons.

Slide 3: Periodic table

The Periodic Table

When you study them, you find that the number of electrons is different for each element and that each element on the periodic table is arranged in order from the element whose atoms contain only one electron (hydrogen) to the element whose atoms contain 118 electrons (ununoctium). You can also see that all those elements are in order following from left to right for each row, following the rows from top to bottom.

You can use models of the electronic structure of atoms to explain the chemical properties of elements when you describe how the electrons are arranged around the nucleus.

Slide 4: Shells

Shells and subshells

Your model of electronic structure begins with electrons divided into primary groupings called shells. Those shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within each shell, you see electrons grouped into subshells.

Slide 5: Subshells

The number of subshells varies for each shell, but follows a pattern that you can follow. Part of your pattern is that the number of subshells is equal to the number of each shell.

Slide 6:

Here is your pattern for shells. The first shell, it has one subshell

Slide 7:

while the second shell, it has two subshells,

Slide 8:

the third shell, it has three subshells,

Slide 9:

and so on.

How many shells do you think the fourth shell has? The fifth shell?

Subshells don't have numbers, but instead they have letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.

Slide 10: s subshells

Within the shells, you find that the first subshell in every shell of electrons is the s subshell. His letter S stands for sharp.

Slide 11: p subshells

Then you find the second subshell, which is found in every electron shell except for the first shell is the p subshell. His letter P stands for principle.

Slide 12: d subshells

Your third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. His letter D stands for diffuse.

Slide 13: f subshells

The fourth subshell, found in the fourth shell and beyond, is the f subshell. His letter F stands for fine.

Slide 14: s, p, d, f, g, h, i...

After the f subshell, you will find more subshells in the larger shells, but the letters for those guys are g, h, i, and so on, following the alphabet. Their letters are not related to any names used by early chemists.

Slide 15: Shells only

Electrons and shells

Next you find that there are a limited number of electrons in each shell in the atomic model.

Only two electrons can fit in your atom's first shell.

Slide 16: Hydrogen

The first element, Hydrogen, has one electron and he is located in the first shell.

Slide 17: Helium

The second element, Helium, has two electrons and they are located in the first shell.

What do you think happens for an element with three electrons?

Slide 18: Lithium

The third element, Lithium, has three electrons, more than the maximum for the first shell, so two of them are in the first shell and one of them in the second shell.

Slide 19: Periodic table period change

You can see this change to the second shell paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.

Slide 20: Beryllium

Your fourth element, Beryllium, has four electrons, two of them in the first shell and two of them in the second shell.

You can see that the second shell can hold a maximum of eight electrons, so the elements in period two use the second shell up to the tenth element,

Slide 21: Neon

Neon, he has ten electrons, two electrons in the first shell and eight electrons in the second shell.

What do you think happens for an element with eleven electrons?

Slide 22: Sodium

When you examine the eleventh element, sodium, he has more electrons than the first and second shells can hold and his eleventh electron is in the third shell.

Slide 23: Periodic table period change

You can see the change from the second electron shell to the third electron shell paralleled in the periodic table by a shift from the second period to the third period.

Slide 24: Argon

You can also see that the pattern of electrons being added for the third period follows the same pattern as the second period to element 18, Argon.

Be careful here as Argon is not the last element to add electrons to the third shell even though he is the last element in period three.

Slide 25: Periodic table

You can look and see the periodic table showing a second pattern of the atomic model where the fourth period of the table represents parts of his third and fourth shells of electrons. Your second pattern for the atomic model is his pattern for his subshells.

Slide 26: Generic subshells with electrons

Electrons in the subshells

You can find that each atom has a limited number of electrons in each of his shells and also in each of his subshells.

You will also find atoms fill their shells with electrons in numerical order. Atoms also fill their subshells within each shell with electrons in the order s, p, d, f, g, and so on.

Slide 27: Hydrogen

If you could see the atom, you would see that Hydrogen has his one electron in his first subshell in his first shell, called his 1s subshell.

Slide 28: Helium

Then you would see that Helium has his two electrons in his first subshell in his first shell, called his 1s subshell.

Slide 29: Lithium

But you would find that Lithium has three electrons, two in his 1s subshell and one in his first subshell in the second shell, called the 2s subshell.

Slide 30: Beryllium

Beryllium has four electrons, two in his 1s subshell and two in his 2s subshell.

What do you think happens for an element with five electrons?

Slide 31: Boron

When you get to Element number five, Boron, he has five electrons with two in his 1s subshell and two in his 2s subshell. The fifth electron is located in the second subshell of his second shell, called the 2p subshell.

Slide 32: Carbon

You see that Element six, Carbon, continues the pattern, with his six electrons, two in his 1s subshell, two in his 2s subshell, and two in his 2p subshell.

Slide 33: Neon

Eventually you have the 2p subshell can hold a maximum of six electrons and element ten, Neon, is the element with his 2p subshell full.

What do you think happens for sodium with his eleven electrons?

Slide 34: Sodium

When the next element has eleven electrons, you see his last electron is in the first subshell of his third shell, called the 3s subshell.

Slide 35: s block

The s block elements

Notice that each of the first two elements of every period in the periodic table has his outermost electrons in s subshells, so elements in the first two columns of the periodic table are called s block elements.

Slide 36: Magnesium

The twelfth element, Magnesium, is part of the s block, with his outermost two electrons in the 3s subshell.

Slide 37: Aluminum

You can see the next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of his third shell, the 3p subshell.

Slide 38: p block

The p block elements

Similar to how each of the first two elements of each period had his outermost electron located in an s subshell, see that each of the last six elements of each period has his outermost electrons located in a p subshell. These elements are called the p block elements and you can explain many properties of these elements using p subshells.

Slide 39: Potassium & Calcium

Your first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.

Slide 40: Scandium

But you see the next element, Scandium, has his next electron added the outermost subshell—and this subshell is part of his third shell instead of the fourth. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells.

See that Scandium has two electrons in the 4s subshell, following the pattern of the two elements before him, but he has one electron in the third subshell of his third shell, called the 3d subshell.

Slide 41: Titanium

Notice that the next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d and

Slide 42: 3d subshell & Zinc

This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.

Slide 43: Periodic table, period 4 highlighted

Linking the electron arrangement to the Periodic Table

See how this pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.

Slide 44: Periodic table, period 5 highlighted

You can see how the pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.

What do you think the name is for the group of elements in the middle of the periodic table?

Slide 45: d block

The d block elements

You can call the group of elements in the middle ten columns of the periodic table the d block because each of these elements has between one and ten electrons in his d subshell.

Slide 46: f subshells

Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to their d subshells and the f subshells of their inner shells.

Slide 47: periodic table and f subshells (all shaded at bottom)

You can see how this pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. Also see how the periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons.

Slide 48: Sixth period: s subshell

Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.

Slide 49: Sixth period: f subshell

Notice how before filling the 5d subshell, the next fourteen elements, Lanthanum to Ytterbium, fill their 4f subshells.

Slide 50: Sixth period: d subshell

Then the next ten elements fill their 5d subshell and

Slide 51: Sixth period: p subshell

The last six elements fill their 6p subshell.

What do you think the order of the subshells for the seventh period is?

Slide 52: Seventh period

The elements in period seven follow the same pattern as those in period six.

Slide 53: f block (middle)

The f block elements

Notice that even though these elements that fill their f subshells would ideally be located in the middle left of the periodic table,

Slide 54: f block (bottom)

they are usually placed at the bottom of most periodic tables. You can call them the f block elements. You can also call them the Lanthanides and Actinides after the elements that begin each row.

Slide 55: Shells and subshells (empty)

Electron configurations

You can replace drawing diagrams for the electronic structure of atoms with a written shorthand notation called electron configuration. Your electron configuration represents the shells and subshells that have electrons with letter and number combinations: 1s, 2s, 2p, 3s, 3p and so on. After each letter, you put

a superscript number that indicates how many electrons are located in that subshell.

You will see that the pattern for electron configurations is the most straightforward for the first 18 elements.

Slide 56: H

Hydrogen has a configuration of $1s^1$ because he has one electron in the s subshell in his first shell.

Slide 57: He

Helium has a configuration of $1s^2$ because he has two electrons in the s subshell in his first shell.

What do you think the configuration is for an element who has three electrons?

Slide 58: Li

Notice that since there is no 1p subshell, Lithium has a configuration of $1s^2 2s^1$ because he has two electrons in the s subshell in his first shell and one electron in the s subshell of his second shell.

Slide 59: Be

Beryllium continues the pattern with $1s^2 2s^2$.

Slide 60: B

Now you can see that since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^2 2s^2 2p^1$ with two electrons in the s subshell in his first shell, two electrons in the s subshell of his second shell and one electron in the p subshell of his second shell.

Slide 61: up to Ne

When you continue across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^2 2s^2 2p^6$.

What do you think the configuration is for sodium with his eleven electrons?

Slide 62: Na & third period

Then when you begin the third period with sodium, there is configuration $1s^2 2s^2 2p^6 3s^1$ for his eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.

Slide 63: K & Ca

Configuration changes in the fourth period

For the fourth period, you will see the pattern changes with the d block elements.

The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.

Slide 64: Sc and d block

With scandium and the other d block elements, you see the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.

Slide 65: d1 to d10

You will find the general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.

Slide 66: P table and La

The other d block elements follow the same general pattern as those in the fourth period do, but you find yet another pattern layer is added for the f block elements, beginning with Lanthanum in period 6.

Slide 67: Atomic sizes

Electron arrangement and atomic size

You can use the arrangement of electrons into shells and subshells to explain patterns in the sizes of the atoms for different elements.

Atomic size decreases in element families from the largest at the bottom of the periodic table to the smallest at the top, and atomic size also decreases going across the periods of the table from left to right.

Slide 68: Shells comparison

Your electronic structure explanation for the first pattern in atomic size is that if an element is located below another element on the periodic table, then he has more shells of electrons and he is larger.

Is an element in the third period larger or smaller than the element above him?

Slide 69: Periods comparison

For your second pattern, you can explain with electronic structure that while an element to the right side of the periodic table has more electrons than elements to his left do, both he and the elements to the left have the electrons in the same shell of the atom and

Slide 70: More protons

Because an element to the right has more protons, the electrons in his outermost shell feel a stronger attractive force from his nucleus and are therefore closer to the nucleus, making him smaller.

Is an element at the far right of the periodic table larger or smaller than the element to his left?

Slide 71: Blank Periodic Table

Element groups and electronic structure

The elements were originally grouped in the periodic table based on their properties.

You can use the model of electronic structure to explain their properties.

Slide 72: Valence electrons

You will find that the cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of an atom and which are involved in his chemical reactions.

Slide 73: Alkali metals, 1 valence e⁻

Groups of elements, valence electrons, and common ionic charges

Your first group of elements in the periodic table is the alkali metals, each of which has one valence electron in his outermost shell. That electron is always located in the s subshell of his outermost shell and each alkali element is described as an s¹ element. When you remove his one valence electron an alkali metal forms a cation with +1 charge.

Slide 74: Alkaline earth metals, 2 valence e⁻

Your second group of elements in the periodic table is the alkaline earth metals, each of which has two valence electrons. Each of these elements is described as

an s^2 element and each forms a cation with a +2 charge when you remove his two valence electrons.

Slide 75: Group 3A elements, 3 valence e^-

With each element in group 3A of the periodic table, you find he has three electrons in his valence shell and he forms a cation with a +3 charge. Notice that because only two electrons can be in his s subshell, he has a third electron in a p subshell and has an s^2p^1 configuration.

Does an element that loses some of his electrons become positively or negatively charged?

Slide 76: Blank Periodic Table

Your elements on the right side of the periodic table also form ions with similar charges when they gain electrons.

Slide 77: Halogens, 7 valence e^- (one empty spot)

You saw before that each of the halogens in group 7A of the periodic table has seven valence electrons in an s^2p^5 configuration. Each halogen commonly forms an anion with one more electron, giving him a -1 charge. You can explain with Atomic theory that he has an unoccupied space in his valence electron shell and enough attraction from his nucleus to attract and keep an extra electron in his valence shell, making him into an anion.

Slide 78: Chalcogens, 6 valence e^- (two empty spots)

Each of your elements in group 6A commonly forms an anion with two more electrons, giving him a -2 charge. Notice that this charge parallels the fact that he has an s^2p^4 configuration with room for two additional electrons in his outermost p subshell.

Slide 79: Pnictogens, 5 valence e^- (three empty spots)

Each of your elements in group 5A commonly form anions with three more electrons, giving him a -3 charge. Notice that this charge parallels the fact that he has an s^2p^3 configuration with room for three additional electrons in his outermost p subshell.

Does an element that gains electrons become positively or negatively charged?

Slide 80: Group 4A elements, 4 valence e^- (four empty spots)

Your elements in group 4A have a more complicated pattern. When one of these elements forms an anion with four more electrons, he has a -4 charge. Notice that this charge parallels the fact that he has an s^2p^2 configuration with room for four additional electrons in his outermost p subshell. But also be aware that some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.

Slide 81: Noble gases

On the far right of the periodic table you have the noble gases, with full valence shells holding 2 s and 6 p electrons. You may know that these elements do not normally form ions or ionic compounds because it is energetically unfavorable for any of them to add an additional electron to a new valence shell when all of his current electrons partially counteract the attractive force of his nucleus. You can call this counteraction electron shielding in technical chemistry language. How is an element's group related to the number of valence electrons in his atoms?

Slide 82: Summary: P-table and Atomic Model

Conclusion

Atomic sizes and common ionic charges are two of many properties of atoms that you can explain using atomic models of electron configurations with shells and subshells. You have seen how these properties and the model of the atom parallel the organization and structure of the periodic table. The model of the atom you now know and the structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to remove electrons from atoms. You can use the periodic table and the atomic model to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.

Atomic Structure Script: Combination Personalization (You) and Female Personification (She)

Slide 1: Title Slide

Welcome to an instructional video on Atomic Structure

Slide 2: Introduction

Introduction to Atoms

Atoms are the smallest unit of matter that you can still consider an element. You can't call a particle that is smaller than an atom an element, but instead you would call her an elementary particle or a subatomic particle.

Atoms are therefore also the smallest units of the elements.

If you could see an atom, you would see that she consists of electrons and a nucleus with neutrons and protons. When you study chemistry, you are primarily concerned with her electrons.

Slide 3: Periodic table

The Periodic Table

When you study them, you find that the number of electrons is different for each element and that each element on the periodic table is arranged in order from the element whose atoms contain only one electron (hydrogen) to the element whose atoms contain 118 electrons (ununoctium). You can also see that all those elements are in order following from left to right for each row, following the rows from top to bottom.

You can use models of the electronic structure of atoms to explain the chemical properties of elements when you describe how the electrons are arranged around the nucleus.

Slide 4: Shells

Shells and subshells

Your model of electronic structure begins with electrons divided into primary groupings called shells. Those shells are numbered using the natural or counting numbers, 1, 2, 3, 4, and so on. Within each shell, you see electrons grouped into subshells.

Slide 5: Subshells

The number of subshells varies for each shell, but follows a pattern that you can follow. Part of your pattern is that the number of subshells is equal to the number of each shell.

Slide 6:

Here is your pattern for shells. The first shell, she has one subshell

Slide 7:

while the second shell, she has two subshells,

Slide 8:

the third shell, she has three subshells,

Slide 9:

and so on.

How many shells do you think the fourth shell has? The fifth shell?

Subshells don't have numbers, but instead they have letters that correspond to names used by early chemists and physicists who were studying electrons and atoms.

Slide 10: s subshells

Within the shells, you find that the first subshell in every shell of electrons is the s subshell. Her letter S stands for sharp.

Slide 11: p subshells

Then you find the second subshell, which is found in every electron shell except for the first shell is the p subshell. Her letter P stands for principle.

Slide 12: d subshells

Your third subshell, found in the third shell, fourth shell, fifth shell, and beyond, is the d subshell. Her letter D stands for diffuse.

Slide 13: f subshells

The fourth subshell, found in the fourth shell and beyond, is the f subshell. Her letter F stands for fine.

Slide 14: s, p, d, f, g, h, i...

After the f subshell, you will find more subshells in the larger shells, but the letters for those subshells are g, h, i, and so on, following the alphabet. Their letters are not related to any names used by early chemists.

Slide 15: Shells only

Electrons and shells

Next you find that there are a limited number of electrons in each shell in the atomic model.

Only two electrons can fit in your atom's first shell.

Slide 16: Hydrogen

The first element, Hydrogen, has one electron and she is located in the first shell.

Slide 17: Helium

The second element, Helium, has two electrons and they are located in the first shell.

What do you think happens for an element with three electrons?

Slide 18: Lithium

The third element, Lithium, has three electrons, more than the maximum for the first shell, so two of them are in the first shell and one of them in the second shell.

Slide 19: Periodic table period change

You can see this change to the second shell paralleled in the periodic table by a shift from the first row or period of the table to the second period of the table.

Slide 20: Beryllium

Your fourth element, Beryllium, has four electrons, two of them in the first shell and two of them in the second shell.

You can see that the second shell can hold a maximum of eight electrons, so the elements in period two use the second shell up to the tenth element,

Slide 21: Neon

Neon, she has ten electrons, two electrons in the first shell and eight electrons in the second shell.

What do you think happens for an element with eleven electrons?

Slide 22: Sodium

When you examine the eleventh element, sodium, she has more electrons than the first and second shells can hold and her eleventh electron is in the third shell.

Slide 23: Periodic table period change

You can see the change from the second electron shell to the third electron shell paralleled in the periodic table by a shift from the second period to the third period.

Slide 24: Argon

You can also see that the pattern of electrons being added for the third period follows the same pattern as the second period to element 18, Argon.

Be careful here as Argon is not the last element to add electrons to the third shell even though she is the last element in period three.

Slide 25: Periodic table

You can look and see the periodic table showing a second pattern of the atomic model where the fourth period of the table represents parts of her third and fourth shells of electrons. Your second pattern for the atomic model is her pattern for her subshells .

Slide 26: Generic subshells with electrons

Electrons in the subshells

You can find that each atom has a limited number of electrons in each of her shells and also in each of her subshells.

You will also find atoms fill their shells with electrons in numerical order. Atoms also fill their subshells within each shell with electrons in the order s, p, d, f, g, and so on.

Slide 27: Hydrogen

If you could see the atom, you would see that Hydrogen has her one electron in her first subshell in her first shell, called her 1s subshell.

Slide 28: Helium

Then you would see that Helium has her two electrons in her first subshell in her first shell, called her 1s subshell.

Slide 29: Lithium

But you would find that Lithium has three electrons, two in her 1s subshell and one in her first subshell in the second shell, called the 2s subshell.

Slide 30: Beryllium

Beryllium has four electrons, two in her 1s subshell and two in her 2s subshell.

What do you think happens for an element with five electrons?

Slide 31: Boron

When you get to Element number five, Boron, she has five electrons with two in her 1s subshell and two in her 2s subshell. The fifth electron is located in the second subshell of her second shell, called the 2p subshell.

Slide 32: Carbon

You see that Element six, Carbon, continues the pattern, with her six electrons, two in her 1s subshell, two in her 2s subshell, and two in her 2p subshell.

Slide 33: Neon

Eventually you have the 2p subshell holding a maximum of six electrons and element ten, Neon, is the element with her 2p subshell full.

What do you think happens for sodium with her eleven electrons?

Slide 34: Sodium

When the next element has eleven electrons, you see her last electron is in the first subshell of her third shell, called the 3s subshell.

Slide 35: s block

The s block elements

Notice that each of the first two elements of every period in the periodic table has her outermost electrons in s subshells, so elements in the first two columns of the periodic table are called s block elements.

Slide 36: Magnesium

The twelfth element, Magnesium, is part of the s block, with her outermost two electrons in the 3s subshell.

Slide 37: Aluminum

You can see the next element, Aluminum, has thirteen electrons, with two electrons in the 3s subshell and an additional electron, which is located in the second subshell of her third shell, the 3p subshell.

Slide 38: p block

The p block elements

Similar to how each of the first two elements of each period had her outermost electron located in an s subshell, see that each of the last six elements of each period has her outermost electrons located in a p subshell. These elements are called the p block elements and you can explain many properties of these elements using p subshells.

Slide 39: Potassium & Calcium

Your first two elements of the fourth period follow the s-block pattern with the outermost electrons in the 4s subshell.

Slide 40: Scandium

But you see the next element, Scandium, has her next electron added the outermost subshell—and this subshell is part of her third shell instead of the fourth. Chemists explain this pattern as the overlap of the subshells. The overlap does not happen with the first two shells, but becomes more and more substantial with the larger shells.

See that Scandium has two electrons in the 4s subshell, following the pattern of the two elements before her, but she has one electron in the third subshell of her third shell, called the 3d subshell.

Slide 41: Titanium

Notice that the next element, Titanium, continues this pattern with two electrons in the 4s and two electrons in the 3d and

Slide 42: 3d subshell & Zinc

This pattern continues until the 3d subshell holds ten electrons, the maximum capacity. This occurs with the 30th element, Zinc.

Slide 43: Periodic table, period 4 highlighted

Linking the electron arrangement to the Periodic Table

See how this pattern where the fourth period begins with the 4s subshell, then switches to the 3d subshell, and then to the 4p subshell is reflected again in the structure of the periodic table.

Slide 44: Periodic table, period 5 highlighted

You can see how the pattern of the fourth period is repeated again with the fifth period, this time beginning with the 5s subshell, then the 4d subshell, and then the 5p subshell.

What do you think the name is for the group of elements in the middle of the periodic table?

Slide 45: d block

The d block elements

You can call the group of elements in the middle ten columns of the periodic table the d block because each of these elements has between one and ten electrons in her d subshell.

Slide 46: f subshells

Similar to how the fourth and fifth period elements added electrons to the d subshells of inner shells, the sixth and seventh period elements add electrons to their d subshells and the f subshells of their inner shells.

Slide 47: periodic table and f subshells (all shaded at bottom)

You can see how this pattern is similar to the d subshells pattern in that electrons are added to f subshells of previous shells. Also see how the periodic table parallels this f subshell pattern of how electrons are arranged in larger elements, just like the table parallels the arrangement of d subshell electrons..

Slide 48: Sixth period: s subshell

Period six elements begin with two s block elements whose outermost electrons are in the 6s subshell.

Slide 49: Sixth period: f subshell

Notice how before filling the 5d subshell, the next fourteen elements, Lanthanum to Ytterbium, fill their 4f subshells.

Slide 50: Sixth period: d subshell

Then the next ten elements fill their 5d subshell and

Slide 51: Sixth period: p subshell

The last six elements fill their 6p subshell.

What do you think the order of the subshells for the seventh period is?

Slide 52: Seventh period

The elements in period seven follow the same pattern as those in period six.

Slide 53: f block (middle)

The f block elements

Notice that even though these elements that fill their f subshells would ideally be located in the middle left of the periodic table,

Slide 54: f block (bottom)

they are usually placed at the bottom of most periodic tables. You can call them the f block elements. You can also call them the Lanthanides and Actinides after the elements that begin each row.

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Notice that since there is no 1p subshell, Lithium has a configuration of $1s^2 2s^1$ because she has two electrons in the s subshell in her first shell and one electron in the s subshell of her second shell.

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Now you can see that since the second shell has a p subshell in addition to an s subshell, Boron has five electrons in the configuration $1s^2 2s^2 2p^1$ with two electrons in the s subshell in her first shell, two electrons in the s subshell of her second shell and one electron in the p subshell of her second shell.

Slide 61: up to Ne

When you continue across the second period of the table, the pattern continues until Neon with ten electrons in the configuration $1s^2 2s^2 2p^6$.

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Then when you begin the third period with sodium, there is configuration $1s^2 2s^2 2p^6 3s^1$ for her eleven electrons. The elements for the rest of the third period follow the same pattern as the second period.

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For the fourth period, you will see the pattern changes with the d block elements.

The first two elements in the fourth period, potassium and calcium, follow the same pattern as the first three periods.

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With scandium and the other d block elements, you see the pattern changes and these elements have electrons in the 3d subshell, even though they also have electrons in the 4s subshell.

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You will find the general pattern of electron configurations of the d block is to increase the number of electrons in the d subshell one at a time, but there are some exceptions to this pattern.

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You can use the arrangement of electrons into shells and subshells to explain patterns in the sizes of the atoms for different elements.

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For your second pattern, you can explain with electronic structure that while an element to the right side of the periodic table has more electrons than elements to her left do, both she and the elements to the left have the electrons in the same shell of the atom and

Slide 70: More protons

Because an element to the right has protons, the electrons in her outermost shell feel a stronger attractive force from her nucleus and are therefore closer to the nucleus, making her smaller.

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You will find that the cornerstone of these explanations is the idea of valence electrons, namely the electrons located in the outermost shell of an atom and which are involved in her chemical reactions.

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Your first group of elements in the periodic table is the alkali metals, each of which has one valence electron in her outermost shell. That electron is always located in the s subshell of her outermost shell and each alkali element is described as an s¹ element. When you remove her one valence electron an alkali metal forms a cation with +1 charge.

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an s^2 element and each forms a cation with a +2 charge when you remove her two valence electrons.

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With each element in group 3A of the periodic table, you find she has three electrons in her valence shell and she forms a cation with a +3 charge. Notice that because only two electrons can be in her s subshell, she has a third electron in a p subshell and has an s^2p^1 configuration.

Does an element that loses some of her electrons become positively or negatively charged?

Slide 76: Blank Periodic Table

Your elements on the right side of the periodic table also form ions with similar charges when they gain electrons.

Slide 77: Halogens, 7 valence e^- (one empty spot)

You saw before that each of the halogens in group 7A of the periodic table has seven valence electrons in an s^2p^5 configuration. Each halogen commonly forms an anion with one more electron, giving her a -1 charge. You can explain with Atomic theory that she has an unoccupied space in her valence electron shell and enough attraction from her nucleus to attract and keep an extra electron in her valence shell, making her into an anion.

Slide 78: Chalcogens, 6 valence e^- (two empty spots)

Each of your elements in group 6A commonly forms an anion with two more electrons, giving her a -2 charge. Notice that this charge parallels the fact that she has an s^2p^4 configuration with room for two additional electrons in her outermost p subshell.

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Each of your elements in group 5A commonly form anions with three more electrons, giving her a -3 charge. Notice that this charge parallels the fact that she has an s^2p^3 configuration with room for three additional electrons in her outermost p subshell.

Does an element that gains electrons become positively or negatively charged?

Slide 80: Group 4A elements, 4 valence e^- (four empty spots)

Your elements in group 4A have a more complicated pattern. When one of these elements forms an anion with four more electrons, she has a -4 charge. Notice that this charge parallels the fact that she has an s^2p^2 configuration with room for four additional electrons in her outermost p subshell. But also be aware that some of these elements form cations with +4 charges that result when the four electrons in their valence shell are removed.

Slide 81: Noble gases

On the far right of the periodic table you have the noble gases, with full valence shells holding 2 s and 6 p electrons. You may know that these elements do not normally form ions or ionic compounds because it is energetically unfavorable for any of them to add an additional electron to a new valence shell when all of her current electrons partially counteract the attractive force of her nucleus.

You can call this counteraction electron shielding in technical chemistry language.

How is an element's group related to the number of valence electrons in her atoms?

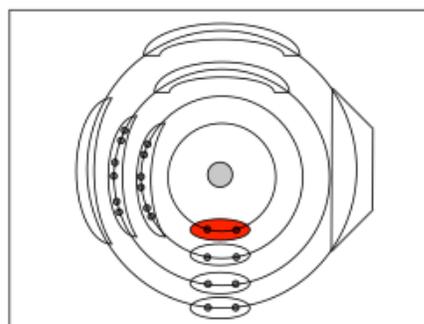
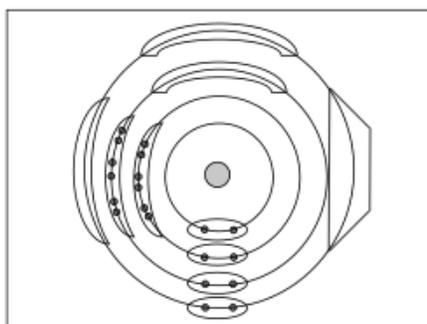
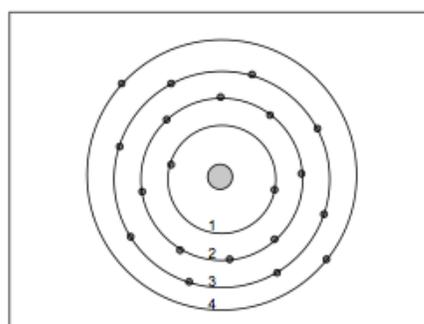
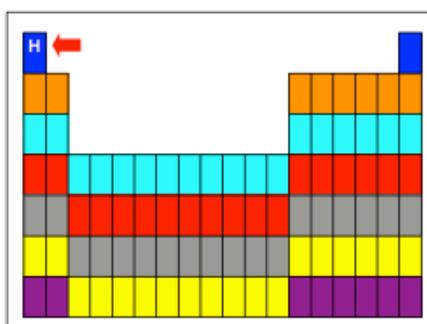
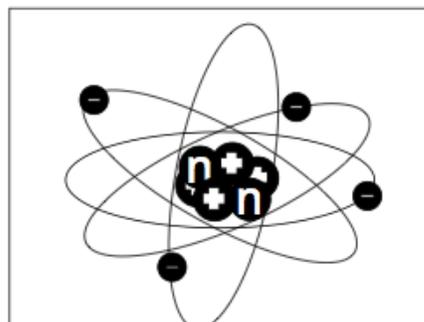
Slide 82: Summary: P-table and Atomic Model

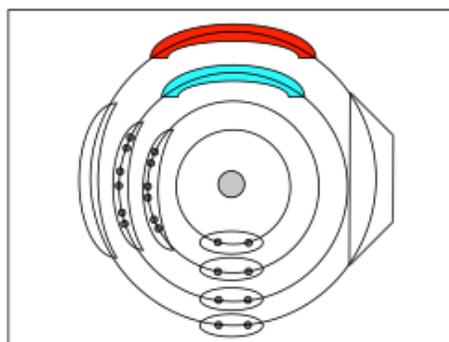
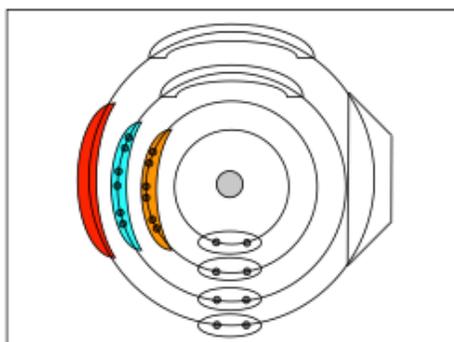
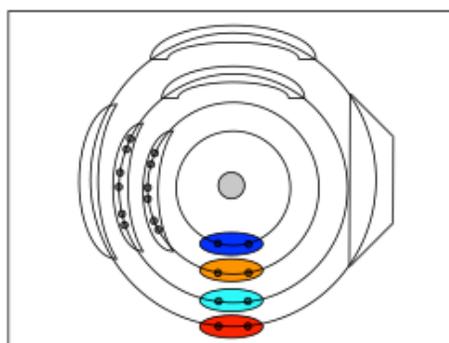
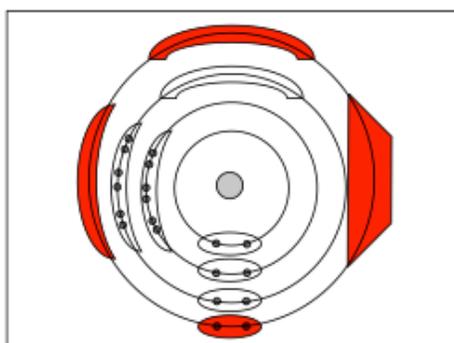
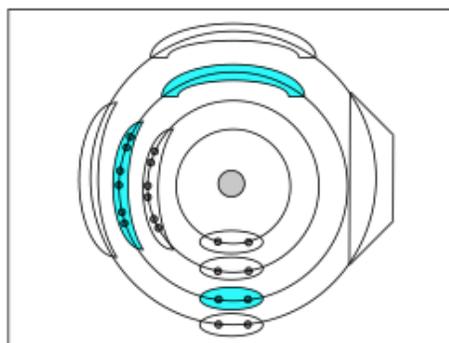
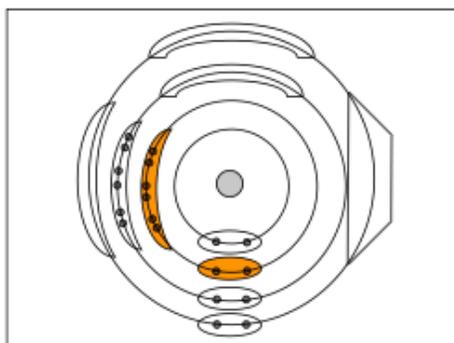
Conclusion

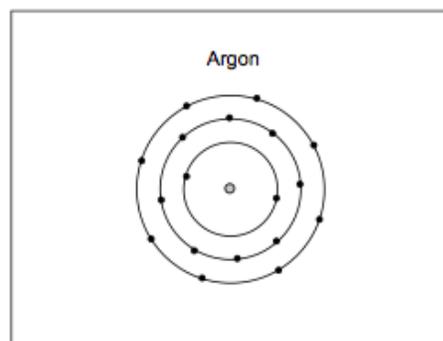
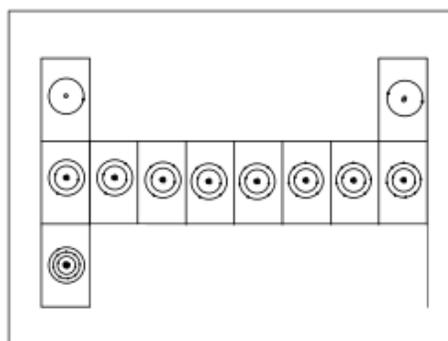
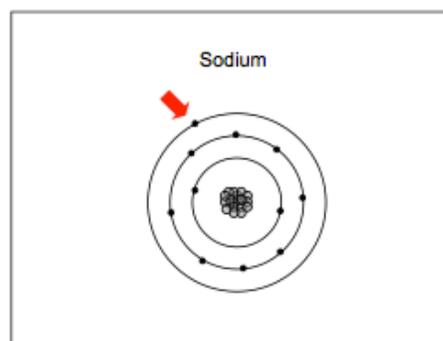
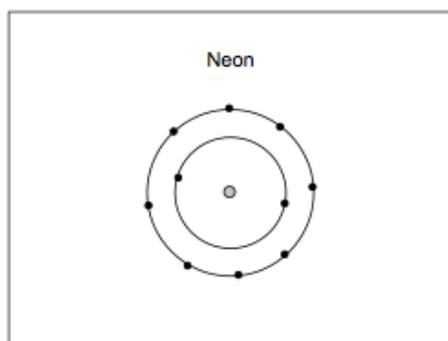
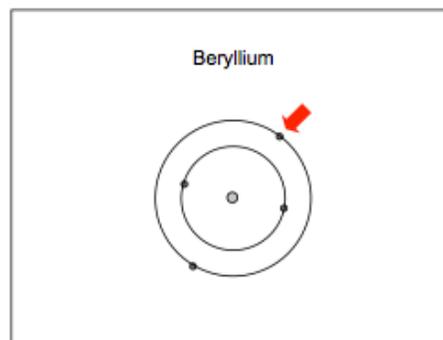
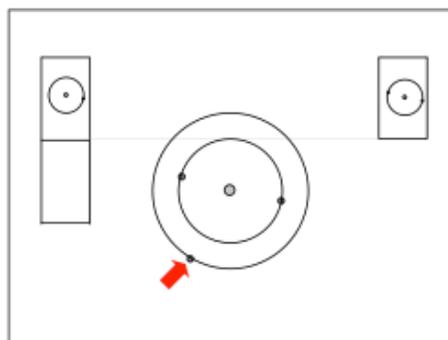
Atomic sizes and common ionic charges are two of many properties of atoms that you can explain using atomic models of electron configurations with shells and subshells. You have seen how these properties and the model of the atom parallel the organization and structure of the periodic table. The model of the atom you now know and the structure of the table are primarily a result of studies of other properties, especially ionization energy—the amount of energy required to removed electrons from atoms. You can use the periodic table and the atomic model to explain many more properties of atoms and the utility of the table is why it is considered one of the greatest theories of chemistry, if not all of science.

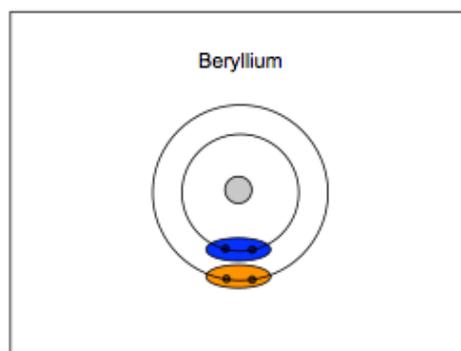
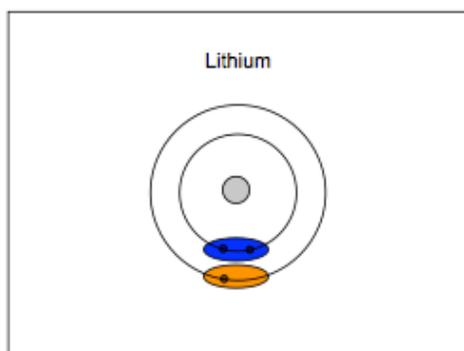
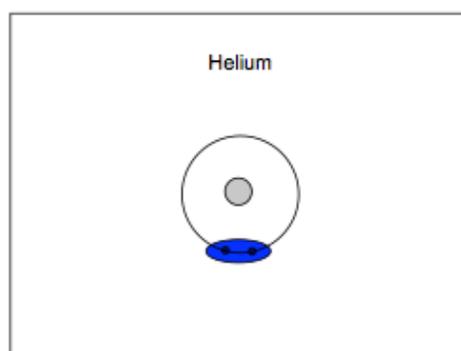
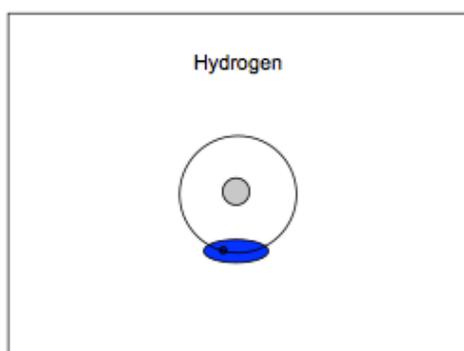
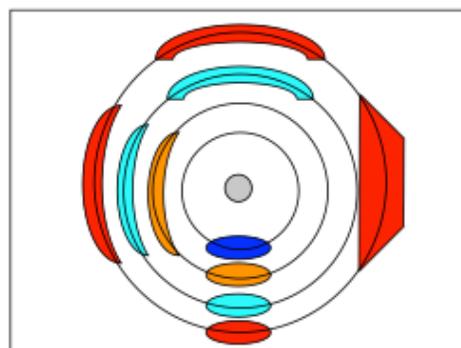
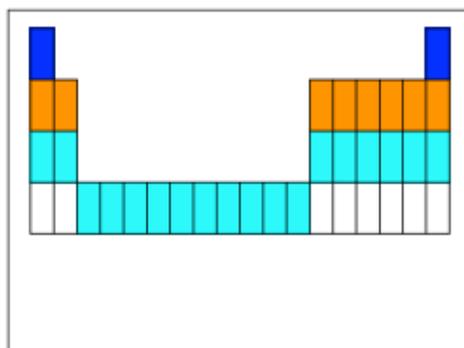
Appendix H: Slides

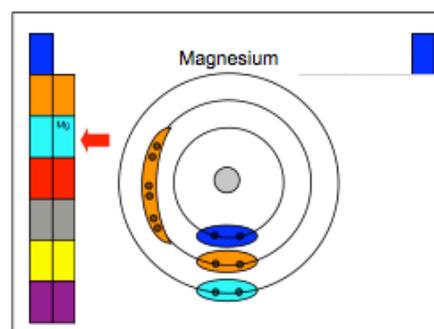
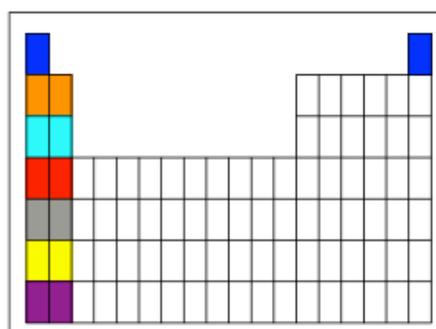
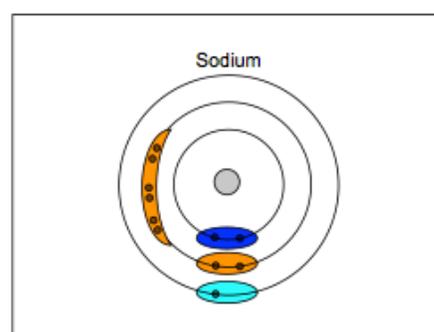
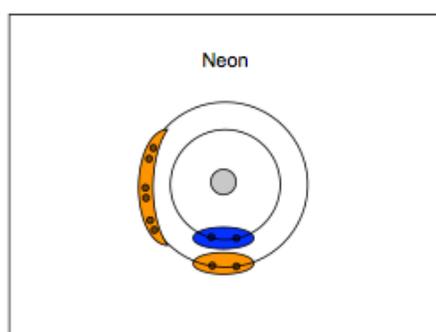
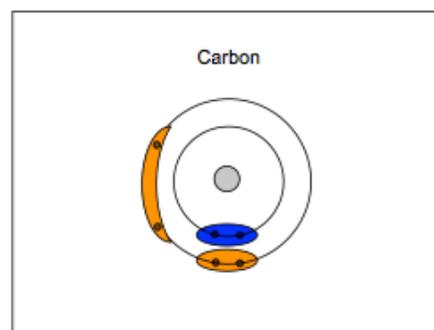
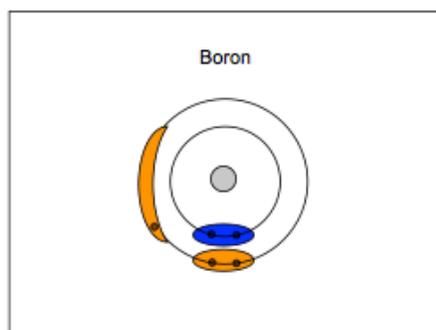
Atomic Structure

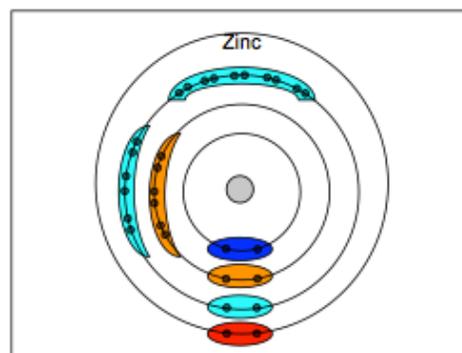
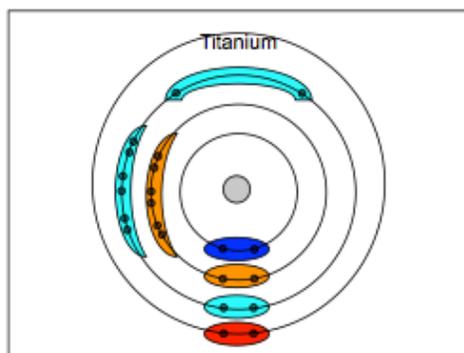
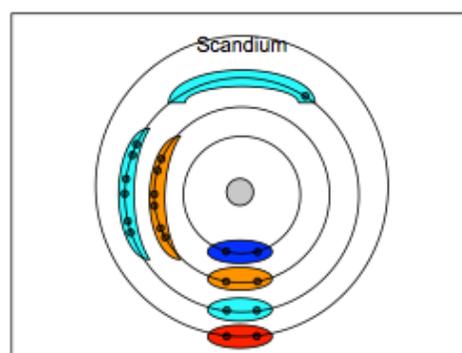
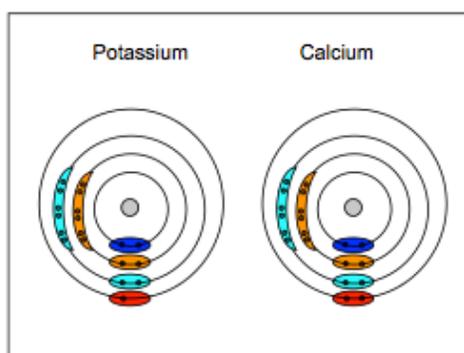
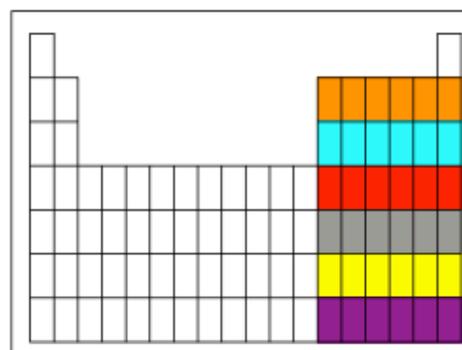
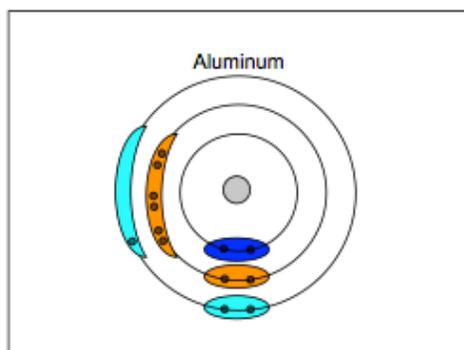


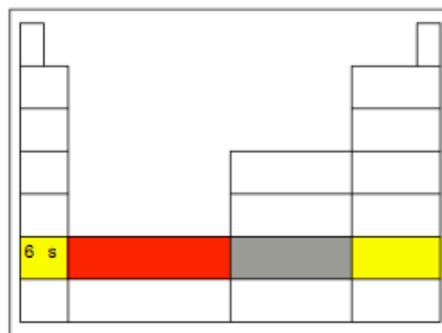
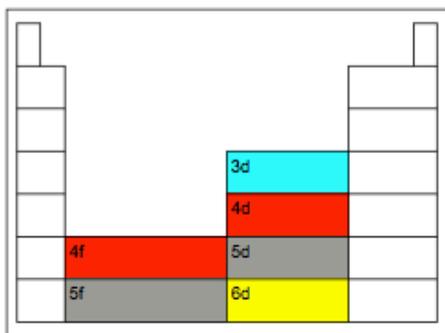
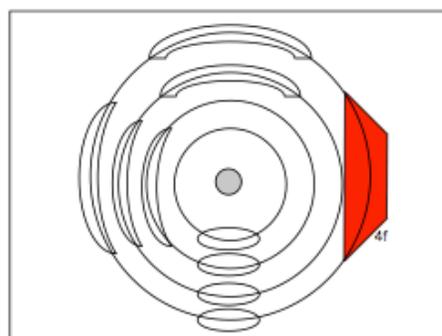
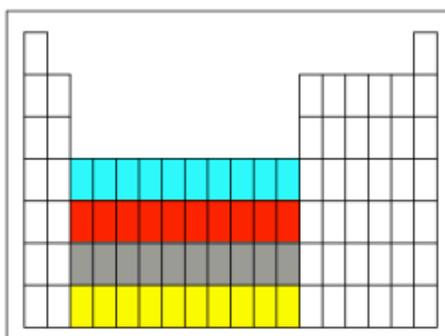
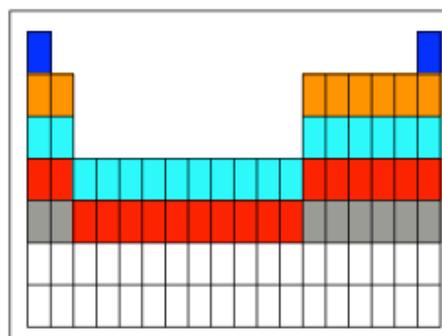
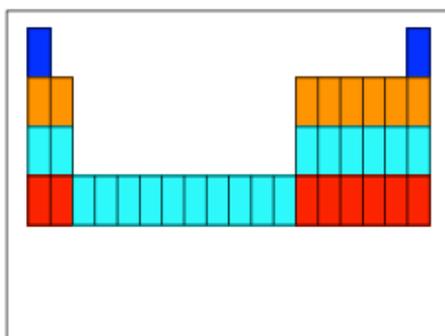


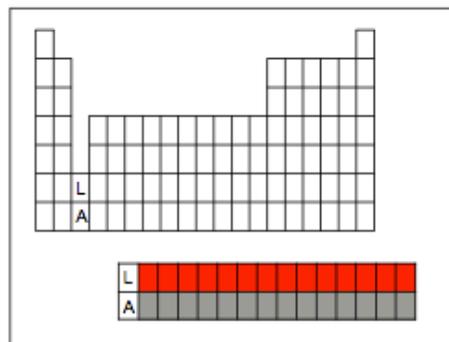
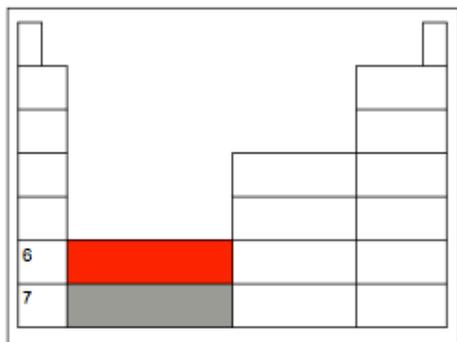
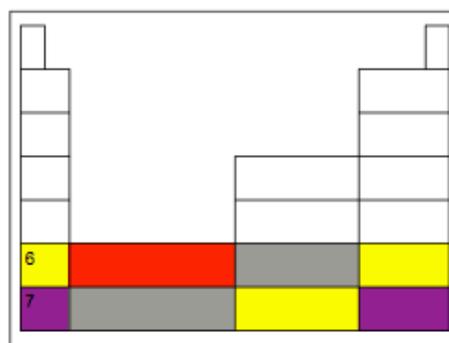
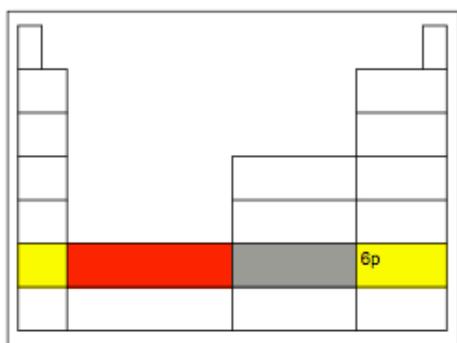
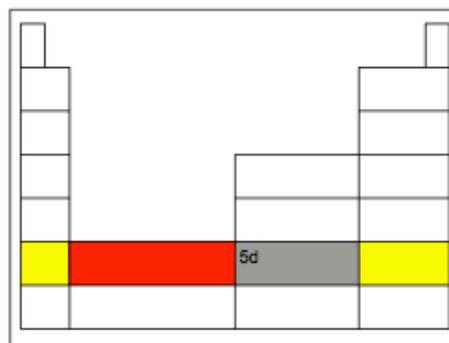
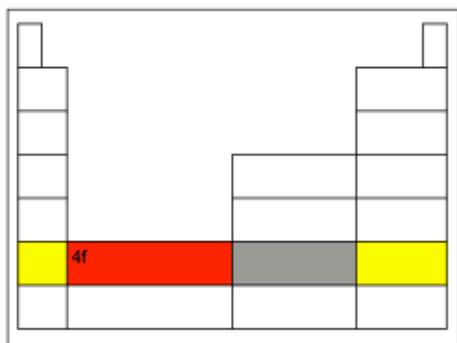


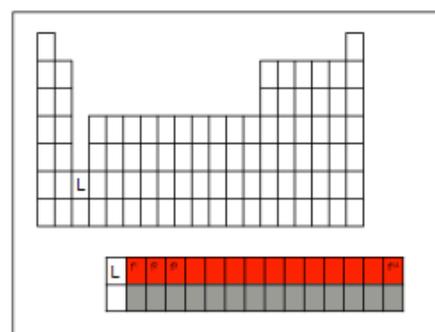
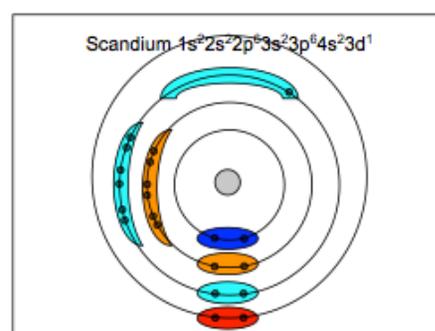
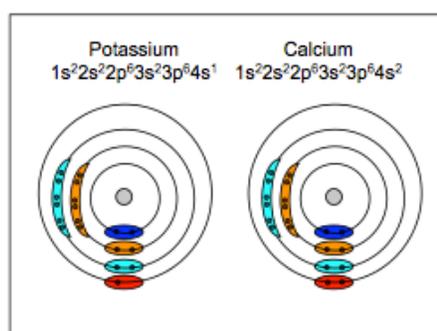
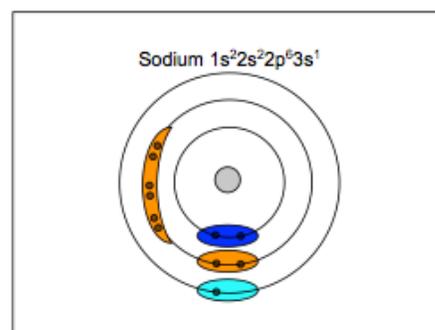
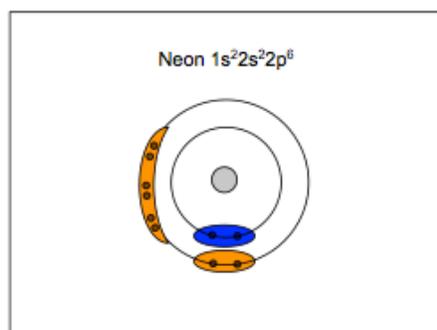


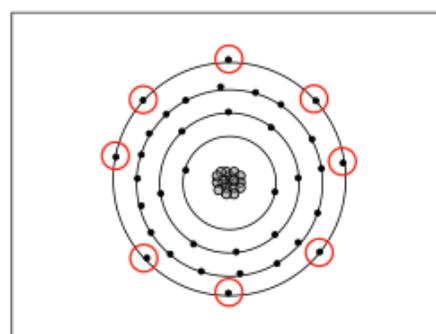
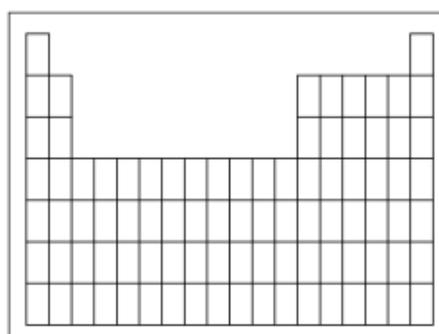
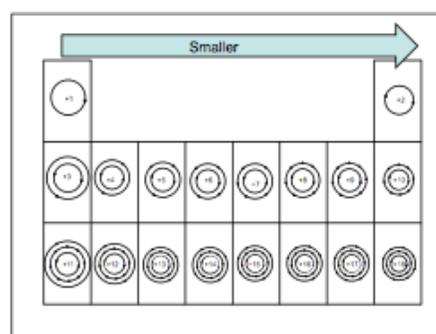
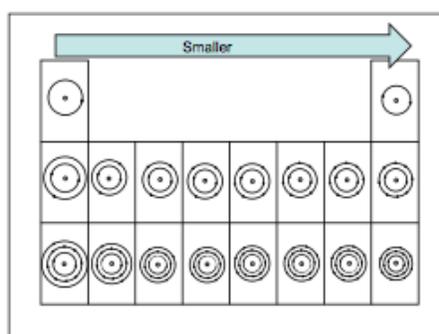
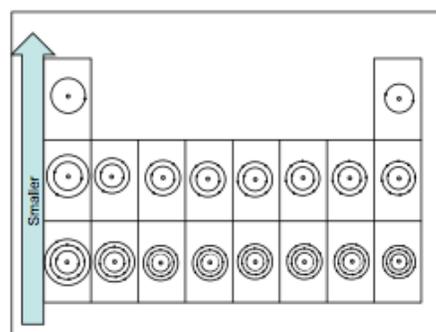
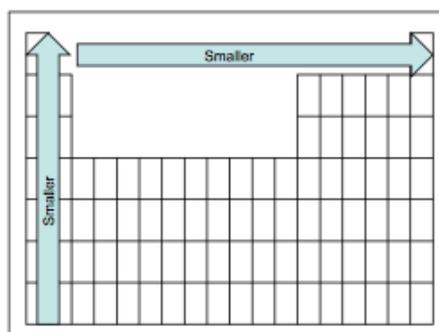


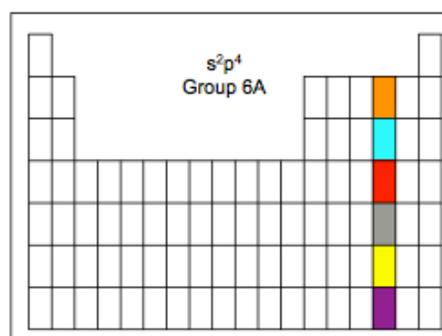
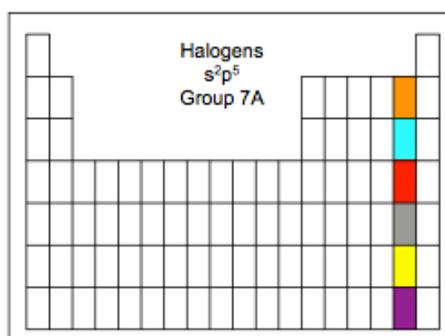
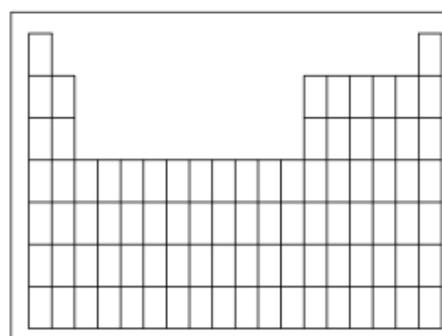
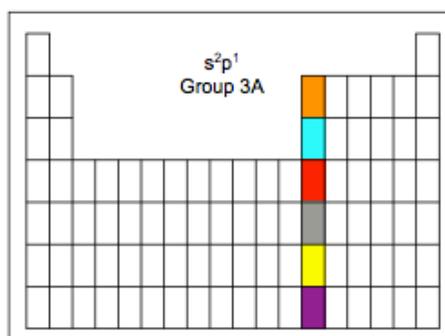
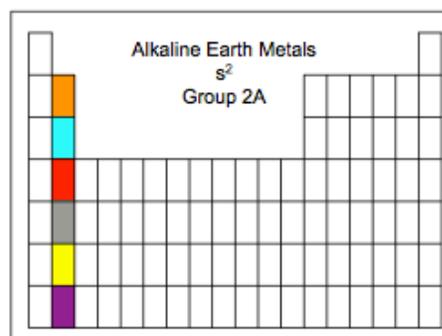
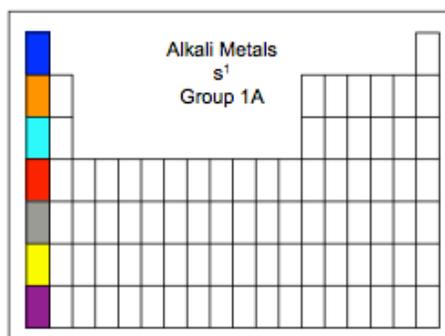


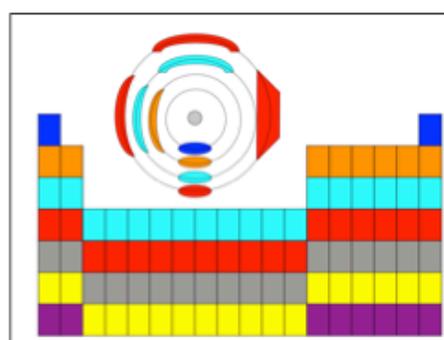
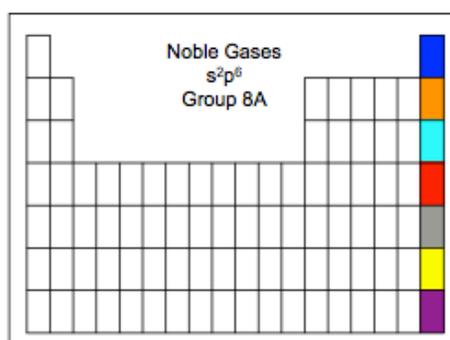
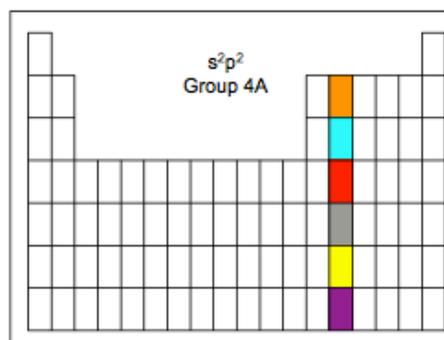
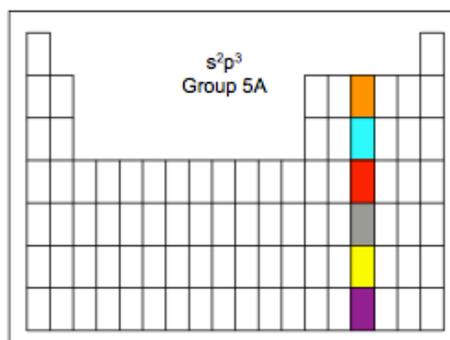




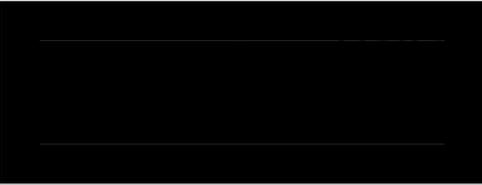








Appendix I: Permission Letters



November 10, 2011

Institutional Review Board for the Protection of Human Subjects
University of San Francisco
2130 Fulton Street
San Francisco, CA 94117

Dear Members of the Committee:

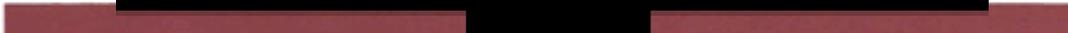
On behalf of the , I am writing to formally indicate our awareness of the research proposed by Mr. Shannon Halkyard, a student at USF. We are aware that Mr. Halkyard intends to conduct his research by administering a pre-test, an instructional video, a survey, and a post-test to our students.

I am also aware of Mr. Halkyard's intention to use passive parental response. Parents and guardians will be given the choice to opt out of participation in the study, but if they do not indicate their desire to opt out, we will assume that they are giving permission for their children to participate. Parents will be given the opportunity to opt out by using the consent form, by email, or verbally. Given that students are expected to benefit from participation in the study by learning about chemistry, that Mr. Halkyard is collecting data anonymously, and that students may opt out of participating or end their participation at any time, I am comfortable that participants will not be harmed and that passive parental consent is acceptable.

I am responsible for student relations. As the head of school, I give Mr. Halkyard permission to conduct his research in our school.

If you have any questions or concerns, please feel free to contact my office at .

Sincerely,

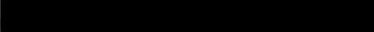




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San Francisco, CA 94117

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I am responsible for student relations. As the head of school, I give Mr. Halkyard permission to conduct his research in our school.

If you have any questions or concerns, please feel free to contact my office at 

Sincerely, 





February 1, 2012

Institutional Review Board for the Protection of Human Subjects
University of San Francisco
2130 Fulton Street
San Francisco, CA 94117

Dear Members of the Committee:

On behalf of [REDACTED] I am writing to formally indicate our awareness of the research proposed by Mr. Shannon Halkyard, a student at USF. We are aware that Mr. Halkyard intends to conduct his research by administering a pre-test, an instructional video, a survey, and a post-test to our students.

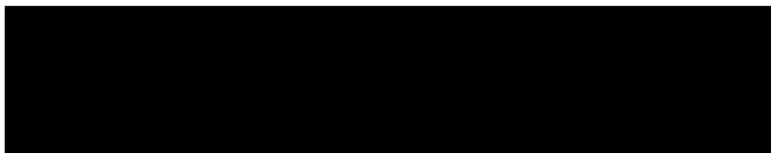
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I am responsible for student relations. As the principal of school, I give Mr. Halkyard permission to conduct his research in our school.

If you have any questions or concerns, please feel free to contact my office at [REDACTED] x234.

Sincerely,





February 9, 2012

Institutional Review Board for the Protection of Human Subjects
University of San Francisco
2130 Fulton Street
San Francisco, CA 94117

Dear Members of the Committee:

On behalf of [REDACTED] I am writing to formally indicate our awareness of the research proposed by Mr. Shannon Halkyard, a student at USF. We are aware that Mr. Halkyard intends to conduct his research by administering a pre-test, an instructional video, a survey, and a post-test to our students.

I am also aware of Mr. Halkyard's intention to use passive parental response. Parents and guardians will be given the choice to opt out of participation in the study, but if they do not indicate their desire to opt out, we will assume that they are giving permission for their children to participate. Parents will be given the opportunity to opt out by using the consent form, by email, or verbally. Given that students are expected to benefit from participation in the study by learning about chemistry, that Mr. Halkyard is collecting data anonymously, and that students may opt out of participating or end their participation at any time, I am comfortable that participants will not be harmed and that passive parental consent is acceptable.

I am responsible for all students at [REDACTED] and am the principal of the institution. I give Mr. Halkyard permission to conduct his research in our school.

If you have any questions or concerns, please feel free to contact my office at [REDACTED] extension 859.

Sincerely,


[REDACTED]

[REDACTED]

Appendix J: Informed Consent Forms

PARENTAL CONSENT FOR RESEARCH PARTICIPATION

Purpose and Background

Mr. Shannon Halkyard, graduate student at the University of San Francisco is doing a study on multimedia learning in science and gender. Because of the challenge presented by complex science concepts and because of potentially different responses of boys and girls to different presentations of those concepts, the researcher is interested in learning whether children have different responses to and different learning results from different versions of instructional chemistry videos. My child is being asked to participate because he/she is a student at a school that has agreed to allow Mr. Halkyard to conduct his study there.

Procedures

If I agree to allow my child to be in this study, the following will happen: My child will complete a short pre-test about a topic in chemistry, watch a twenty minute instructional chemistry video, complete a survey about the video, and answer post-test questions to measure how much my child learned from watching the video.

Risks and/or Discomforts

1. My child may become uncomfortable or upset during the pre-test, video, survey, or post-test; if this happens, the researcher will attempt to comfort my child. If my child continues to be upset, the researchers will allow my child to leave the study area to another room in the school chosen by a teacher or school administrator.
2. Participation in research may mean a loss of confidentiality. Study records will be kept anonymous and as confidential as is possible. The only personal information that will be requested from my child is my child's gender. No other potentially identifying information will be asked. My child will be given a randomly chosen identification number to use with the tests and survey and will not provide her/his name. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files and on password-protected computers at all times. Only study personnel will have access to the files.

Benefits

My child may benefit from learning some or all of the content from the instructional video. Other anticipated benefits of this study are a better understanding of how changes to instructional videos can improve student learning and a better understanding of how girls and boys react (differently and/or similarly) to those instructional changes.

Costs/Financial Considerations

There will be no costs to me or to my child as a result of taking part in this study.

Payment/Reimbursement

Neither my child nor I will be reimbursed for participation in this study.

Questions

I have talked to Mr. Halkyard about this study and have had my questions answered. If I have further questions about the study, I may call him at (415) 713-9259. If I have any questions or comments about participation in this study, I should first talk with the researchers. If for some reason I do not wish to do this, I may contact the IRBPHS, which is concerned with protection of volunteers in research projects. I may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message,

by FAX at (415) 422-5528, by e-mailing IRBPHS@usfca.edu, or by writing to the:
 IRBPHS, Department of Counseling Psychology
 Education Building, University of San
 Francisco, 2130 Fulton
 Street, San Francisco, CA 94117-1080.

Consent

I have been given a copy of the “Research Subject’s Bill of Rights,” and I have been given a copy of this consent form to keep. PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to have my child be in this study, or to withdraw my child from it at any point. My decision as to whether or not to have my child participate in this study will have no influence on my child’s present or future status as a patient in my pediatrician’s office.

Please sign ONLY ONE of the places below.

AGREEMENT SIGNATURE:

My signature below indicates that I AGREE to allow my child to participate in this study.

 Signature of Student/Participant’s Parent/Guardian

 Date of Signature

DISAGREEMENT SIGNATURE:

My signature below indicates that I DO NOT AGREE to allow my child to participate in this study.

 Signature of Student/Participant’s Parent/Guardian

 Date of Signature

 Signature of Researcher Obtaining Consent

 Date of Signature

INFORMED CONSENT FORM
UNIVERSITY OF SAN FRANCISCO
CONSENT TO BE A RESEARCH SUBJECT

Purpose and Background

Mr. Shannon Halkyard, a graduate student in the School of Education at the University of San Francisco is doing a study on multimedia learning materials for chemistry. More and more teachers and students are using audiovisual instructional videos for learning and there are many ways to create the audio and visual parts of these videos. Mr. Halkyard is interested in how different ways to create the videos affects how students learn and how the differences could affect boys and girls differently.

I am being asked to participate because I am a high school student who has or will study chemistry.

Procedures

If I agree to be a participant in this study, the following will happen:

1. I will complete a short test on the material in the video to measure how much of the material I already know and I will answer two questions to indicate my gender and my age.
2. I will watch one of six different versions of the video.
3. I will complete a survey on the video and a post-test to measure how much I learned from watching the video.
4. All of the above will happen in a computer lab at my school.

Risks and/or Discomforts

1. It is possible that some of the questions on the tests or survey may make me feel uncomfortable, but I am free to decline to answer any questions I do not wish to answer or to stop participation at any time.
2. Participation in research may mean a loss of confidentiality. Your name or address will not be recorded for the study. Instead you will be given a random identification number to use on the tests and survey. Study records will be kept as confidential as is possible. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.
3. Because the time required for my participation may be up to 60 minutes, I

may become tired or bored.

Benefits

I may learn some new chemistry from participating in this study and I may also learn about the kinds of questions that are used to measure what I know about this area of chemistry. This study may also provide a better understanding of how to change the way instructional videos are made to improve learning and to improve science education for girls and boys in different ways.

Costs/Financial Considerations

There will be no financial costs to me as a result of taking part in this study.

Payment/Reimbursement

There is no payment for participating in this study.

Questions

I have talked to Mr. Halkyard about this study and have had my questions answered. If I have further questions about the study, I may call him at (415) 713-9259.

If I have any questions or comments about participation in this study, I should first talk with the researchers. If for some reason I do not wish to do this, I may contact the IRBPHS, which is concerned with protection of volunteers in research projects. I may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Psychology, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080.

Consent

I have been given a copy of the "Research Subject's Bill of Rights" and I have been given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to be in this study, or to withdraw from it at any point. My decision as to whether or not to participate in this study will have no influence on my present or future status as a student or employee at USF.

My signature below indicates that I agree to participate in this study.

Participant's Signature

Date of Signature

Signature of Person Obtaining Consent

Date of Signature

Appendix K: Cover Letters

First email letter/Cover letter for consent

January 1, 2012

Mr. John Doe
123 Sunny Circle
Anywhere, CA 90000

Dear Mr. Doe:

My name is Shannon Halkyard and I am a graduate student in the School of Education at the University of San Francisco. I am doing a study on using audiovisual learning materials to learn chemistry. I am interested in how different ways of creating the audiovisual materials can improve learning results and how these results might vary for boys and girls. Your child's school has given approval to me to conduct this research.

Your child is being asked to participate in this research study because her or his school has agreed to let me conduct my study there. I obtained your name from the school mailing list. If you agree to allow your child to be in this study, she or he will participate in the computer lab at her or his school. The study will include a pre-test to measure prior knowledge of chemistry, an instructional video to watch, a survey after the video, and a post-test to measure how much your child learned from the video.

It is possible that some of the questions on the survey may make your child feel uncomfortable, but she or he is free to decline to answer any questions, or to stop participation at any time. Although your child will not be asked to give her or his name on the tests or survey, I will know that she or he was asked to participate in the research because I sent you this letter. Participation in research may mean a loss of confidentiality. Study records will be kept as confidential as is possible. The only personal information to be collected will be age and gender. Participants will be given random identification numbers to use on the tests and surveys. The identification numbers will not be linked any personal information besides age and gender. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files. Individual results will not be shared with personnel of your child's school.

Your child may benefit from participating in this study by learning about chemistry. As well, this study may improve our understanding of how to design instructional videos to better improve student learning and how to design videos that specifically improve learning for girls and boys.

There will be no costs to you or your child as a result of taking part in this study, nor will you or your child be reimbursed for your participation in this study.

If you have questions about the research, you may contact me at (415) 713-9259. If you have further questions about the study, you may contact the IRBPHS at the University of San Francisco, which is concerned with protection of volunteers in research projects. You may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Counseling Psychology Department, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1071.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You and your child are free to decline to be in this study, or to withdraw from it at any point. Your child's school is aware of this study but does not require that your child participate in this research and your decision as to whether or not to participate will have no influence on your or your child's present or future status as a parent, student, or employee at the school.

Thank you for your attention. If you and your child agree to participate, please complete the attached consent documents and return them with your child to the school (or you may do nothing). If you do not or your child does not wish to participate in the study, you can indicate so on the form and return it to the school, or your child can inform me at any time and she or he will not be included in the study.

Sincerely,

Shannon Halkyard
Graduate Student
University of San Francisco

Second email letter

January 15, 2012

Mr. John Doe
123 Sunny Circle
Anywhere, CA 90000

Dear Mr. Doe:

My name is Shannon Halkyard and I am a graduate student in the School of Education at the University of San Francisco. I have contacted you previously about a study I am conducting at your child's school. If you have already responded to my previous email or letter, please disregard the rest of this email. If you have changed your mind about your child's participation, please notify me by email or through the consent form that you or your child have decided not to participate in the study.

I am doing a study on using audiovisual learning materials to learn chemistry. I am interested in how different ways of creating the audiovisual materials can improve learning results and how these results might vary for boys and girls. Your child's school has given approval to me to conduct this research.

Your child is being asked to participate in this research study because her or his school has agreed to let me conduct my study there. I obtained your name from the school mailing list. If you agree to allow your child to be in this study, she or he will participate in the computer lab at her or his school. The study will include a pre-test to measure prior knowledge of chemistry, an instructional video to watch, a survey after the video, and a post-test to measure how much your child learned from the video.

It is possible that some of the questions on the survey may make your child feel uncomfortable, but she or he is free to decline to answer any questions, or to stop participation at any time. Although your child will not be asked to give her or his name on the tests or survey, I will know that she or he was asked to participate in the research because I sent you this letter. Participation in research may mean a loss of confidentiality. Study records will be kept as confidential as is possible. The only personal information to be collected will be age and gender. Participants will be given random identification numbers to use on the tests and surveys. The identification numbers will not be linked any personal information besides age and gender. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files. Individual results will not be shared with personnel of your child's school.

Your child may benefit from participating in this study by learning about chemistry. As well, this study may improve our understanding of how to design instructional videos to better improve student learning and how to design videos that specifically improve learning for girls and boys.

There will be no costs to you or your child as a result of taking part in this study, nor will you or your child be reimbursed for your participation in this study.

If you have questions about the research, you may contact me at (415) 713-9259. If you have further questions about the study, you may contact the IRBPHS at the University of San Francisco, which is concerned with protection of volunteers in research projects. You may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Counseling Psychology Department, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1071.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You and your child are free to decline to be in this study, or to withdraw from it at any point. Your child's school is aware of this study but does not require that your child participate in this research and your decision as to whether or not to participate will have no influence on your or your child's present or future status as a parent, student, or employee at the school.

Thank you for your attention. If you and your child agree to participate, please complete the attached consent documents and return them with your child to the school (or you may do nothing). If you do not or your child does not wish to participate in the study, you can indicate so on the form and return it to the school, or your child can inform me at any time and she or he will not be included in the study.

Sincerely,

Shannon Halkyard
Graduate Student
University of San Francisco