

Examining Learner-Content Interaction Importance and Efficacy in Online, Self-Directed
Electronic Professional Development in Science for Elementary Educators in Grades Three – Six

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Key words: online professional development, e-Learning, self-directed professional development,
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ABSTRACT

Stagnant student achievement in science education in the United States has placed an increased emphasis on teacher professional development. Since many elementary educators could benefit from improved science content knowledge—and given the challenge of providing this at a level scalable and sustainable through face-to-face delivery alone—this study sought to understand what types of online self-directed content-interaction strategies are of greatest learner satisfaction and provide the highest learning impact for teachers in grades three – six. Employing Anderson’s Equivalency of Interaction Theorem, and looking at age, years teaching experience, and learning preferences via Kolb and Kolb’s Learning Style Inventory 3.1 (2005), this descriptive study non-randomly sampled 85 educators who passed a series of self-paced interactive web modules to rate their preferences for five different types of content-interactive strategies: (a) simulations, (b) interactive reference, (c) hands-on, (d) personal feedback, and (e) pedagogical implications. Using an online survey and a pre- and postassessment instrument it was found that (a) as age and years teaching experience increase, teachers’ preferences for personal feedback, interactive reference, and simulations increased, (b) teachers’ content knowledge increased significantly after completing the web modules, (c) teachers’ learning style moderately aligned with their preferences for content-interaction strategies, and (d) teachers least preferred the pedagogical implications component. Instructional designers and education administrators selecting professional development for teachers may find this informative. Data from this research support Anderson’s theory that if the content interaction is rich, human interaction may be provided in diminished capacities

Dedication

I would like to first and foremost dedicate this effort to my Lord and Savior, Jesus Christ. He provides comfort, peace, and strength in this turbulent world, and everlasting hope and salvation in the next one. Second, I dedicate this to my father, Pete Byers, and my mother, Carole Byers. Both were outstanding individuals and exemplary parents who gave of their love and support, encouraging me to strive for a life of high moral character, integrity, and one with a spiritual compass to keep it centered. They both knew of this endeavor, which spanned a decade, but passed from this world before it was completed. I know they are looking down from Heaven with a warm smile. This knowledge provides a sense of gratification that is hard to express. I love my parents immensely.

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In closing this dedication, I want to acknowledge my two girls, Natalie and Samantha. These two girls provide a sense of joy for life that energizes me daily. They embody a purity of heart and take pleasure in the simple things. I am truly blessed. Natalie is 12 years old and Samantha is 5 at the time this journey is coming to a close. There is much life yet to live on this Earth, and I look forward to sharing it with them. I hope to be as good a parent to them as my mother and father were to me.

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Chapter 1: Introduction and Need for the Study

Strengthening elementary and middle school teacher science content knowledge and science teaching abilities is a national imperative in the United States. Strategic policies outlined within the America Competes Act (2007) as well as findings and recommendations from the U.S. Department of Education's *National Commission on Mathematics and Science Teaching for the 21st Century* speak directly to the need for improving science content and science pedagogy among elementary and middle school teachers in America ("America Competes Act ", 2007; National Research Council, 1996; No Child Left Behind Act ", 2001; Science., 1993; U.S. Department of Education, 2000c). This emphasis is due in part to the lack of improvement on student achievement in science education at both national and international levels over the last several decades (Bybee, 2008; Organization for Economic Co-operation and Development, 2007; U.S. Department of Education, 2006b; U.S. Department of Education, National Center for Education Statistics, & Institute of Education Sciences, 2008). In response to this, the research community at large is shifting its focus in part toward teacher improvement through professional development (Banilower, Heck, & Weiss, 2007; Council of Chief State School Officers, 2008; Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007; Supovitz & Turner, 2000; K. S. Yoon, Duncan, Lee, & Shapley, 2008), where many elementary educators could benefit from improved science content knowledge, self-confidence, and science teaching skills (Banilower, Smith, Pasley, & Weiss, 2006; Council of Chief State School Officers, 2007a; Heywood, 2007; Horizons Research, 2001; Kennedy, 1998). Given this long-standing imperative and the challenge of supporting the 1.9 million K–8 teachers in the United States (Aud, et al., 2010; U.S. Department of Education, 2006a; U.S. Department of

Education & National Center for Education Statistics, 2009), exploring distributed online professional development models seem axiomatic. Some of the major questions become, if self-directed on-demand professional development is delivered to address the scale and sustainability issue, what type of content-interaction strategies are most desired by elementary teachers of varying age and years experience in science education as compared to their learning style preferences and how effective are these strategies at increasing teachers' content knowledge?

Purpose Statement of Study

This quantitative descriptive study using multiple statistical methods (i.e., paired-sample *t*-tests, correlation analysis, and ANOVAs) examines which features of on-demand, self-paced online professional development are of the greatest import and learning value for upper level elementary teachers in grades three – six. This study focuses specifically on learner-content interaction strategies using Anderson's 2003 Equivalency of Interaction Theorem as a theoretical base. It states that if one of the following three levels of interaction in online learning is rich, the other two may exist in a diminished capacity: (a) learner-learner, (b) learner-instructor, and (c) learner-content. This study focuses on learner-content interaction strategies via on-demand, self-directed electronic professional development. Teachers' age, years teaching experience, and their learning style preference as identified using Kolb's Learning Style Inventory (LSI-3), are analyzed to uncover any significant relationships to five different types of learner content-interaction strategies (i.e., simulation, hands-on, interactive reference, pedagogical implications, and personal feedback), and their perceived effectiveness through completing an online survey. The Kolb LSI-3 has established validity and reliability documented through peer review (Kayes, 2005; A. Y. Kolb & Kolb, 2005; D. A. Kolb, 1999). Teacher content knowledge learning is also

analyzed via a valid and reliable pre- and postassessment instrument aligned with the respective web modules they completed and passed. This study hopes to inform designers of which self-directed e-PD features within content are worthwhile for development from both educator preference and learning efficacy viewpoints. Educator administrators will also be informed as they make decisions regarding the type of professional development opportunities selected for those teachers they support.

Research Questions

Based on a review of the literature this study sought to determine which features of on-demand, self-paced online professional development have the greatest import and learning value for elementary educators and how they differ for online learners with varying characteristics, focusing specifically on learner-content interaction strategies as described by Anderson's 2003 Equivalency of Interaction Theorem. Six hypotheses are posited for examination: (1) Age will be correlated with the type of preferred interaction strategy desired in on-demand, self-directed web modules (e.g., simulation, hands-on, etc.); (2) Years teaching experience will be correlated with the type of preferred interaction strategy desired in on-demand, self-directed web modules; (3) Age will be correlated with achievement as measured via a pre- and postassessment for those that have completed and passed the online self-directed web-based module; (4) Years teaching experience will be correlated with achievement as measured via a pre- and postassessment for those that have completed and passed the online self-directed web-based module; (5) Adult learners will prefer an online interaction strategy that will match their individual learning style when accessing online, self-directed learning that focuses on learner-content interaction as the

primary vehicle for learning; and (6) teachers completing and passing the final assessment for their respective self-directed web modules will demonstrate significant gains in learning.

Organization of the Study

Chapter 1 briefly presents the background and need for the study, the purpose statement, research questions for the study, overall organization of the study and definitions. Chapter 2 covers a review of the relevant literature and theories undergirding this study. It begins with a discussion of the background and current state of affairs of science education in the United States comparing science student achievement scores across both national and international standardized assessments. This section discusses the need to improve our standings through teacher improvement and subdivides into four subsections, with the first focusing on the general importance of teacher's content knowledge (both subject matter knowledge and pedagogical content knowledge) to facilitate student learning. The four other subsections then address the following areas: (a) elementary and middle level teachers' science content knowledge, (b) the inadequacy of existing teacher professional delivery models, (c) the need for K–8 teacher professional development to focus on science content knowledge, and (d) online teacher professional development as a viable compliment to face-to-face professional development. Section two then discusses the primary theory undergirding this study, Anderson's Equivalency of Interaction Theorem (T. Anderson, 2003); includes a review of specific studies across learner-learner, learner-instructor, and learner-content interaction strategies in online professional development; and ends with an overall summary of the literature. Section three of Chapter 2 reviews the purpose of the study, the research questions, and the hypothesis addressed in this study, and closes by enumerating the significance of this study.

Chapter 3 describes the exact steps and procedures undertaken in this study to address the research questions and hypothesis. Information regarding the research design, sampling procedures, data collection instruments and procedures, piloting of the survey instrument, and procedures for data analysis are presented. In Chapter 4 the findings from the study are summarized. In closing this study, Chapter 5 discusses the findings, summary, conclusions, and limitations of the findings. Practical implications of the study are also discussed.

Definitions of Terms and Abbreviations

Content-Interaction Strategies: References the following types of strategies for interaction facilitated within the self-directed content: simulations, hands-on, interactive reference, personal feedback, and pedagogical implications.

Content Knowledge: Refers to teachers' knowledge of science subject matter, science concepts and pedagogical content knowledge.

e-PD: Electronic Professional Development

Hands-On: Narrative description of tangible activity adult learner may engage with at home to help understand the science concept or phenomenon under examination. Typically includes brief description of procedure, and materials that are readily accessible (not complex science chemicals, apparatus, or lengthy lesson plan).

Interactive Reference: The main portion of the online web-based e-PD modules in this study. This includes the general narrative, images, audio narration, check-your-thinking questions, slide shows, and animations or QuickTime movies.

Kolb Learning Style or Preferences Categories (diverging, assimilating, converging, and

accommodating): The Kolb Learning Style Inventory is a 48-item forced ranking of an individual's preferences and styles for learning. Kolb classifies individuals into four categories:

Diverging style focuses on those who prefer to work in groups and enjoy “receiving personalized feedback” as they engage in learning.

Assimilating style identifies those who prefer to learn via lectures, readings, and analytical models focused on abstract concepts. Less people-focused, more interested in ideas.

Converging learning style individuals prefer to learn with simulations and lab experiments focusing on practical applications and uses of knowledge.

Accommodating learning style individuals prefer “hands-on” experiences with predilections for working with others and participating in group projects.

Pedagogical Content Knowledge/Pedagogical Implications: Teachers' understanding of particular subjects and concepts including knowledge of instructional strategies that facilitate student learning in specific grade and content domains, taking into account knowledge of how students learn and as well as an awareness of particular topics that may be more challenging for student understanding.

Personal Feedback: Embedded questions throughout the online e-PD content that includes a formative quiz at the end of each self-contained web module. Questions may be multiple-choice single or multiple answer and involve interactivity such as drag and drop, hotspot identification, or sequencing of items in a question. Users are provided descriptive feedback based on learner selections to responses and in certain instances are provided recommendations and URL links to re-review existing or new content.

PD: Professional Development

Simulations: Employs high level of user control, where learners may change the parameters or values of variables within the self-contained web-learning experience and see the resultant difference in observed phenomenon (e.g., height of object dropped, type of surface ball is rolling across, etc.).

Chapter 2: Background Research

This chapter will provide an overview of the literature and need for this study. It will begin with a review of the current state of affairs of education in the United States and will provide one possible avenue to facilitate improvement: teacher content knowledge at the elementary and middle grade levels. The chapter will then present the literature in support of teacher professional development and specifically online teacher PD followed by a review of the underlying major theory in this study, Anderson's Equivalency of Interaction Theorem (2003) and the related studies that look at learner-learner, learner-content, and learner-instructor interaction. Next, research pertaining to the variables in this study are examined with a summary of the literature that is then followed by the problem statement, research question, and supporting hypotheses for this research. The chapter closes with the significance of this study.

Current State of Affairs in Science Education in the United States

The National Assessment of Educational Progress (NAEP) reports student achievement in science and mathematics for the United States for grades 4, 8, and 12 in one of four categories: (a) Below Basic, (b) Basic, (c) Proficient, or (d) Advanced. In 2005, NAEP reported that only 29% of both fourth- and eighth-grade students performed at or above the proficient level in science, where proficient represents solid academic performance and demonstrated competency of challenging subject matter (U.S. Department of Education, 2006b). This follows a similar pattern for the 2000 NAEP scores as well. Unfortunately, students' performance in science has remained nearly stagnant across fourth- and eighth-grade proficiency levels, negative for science at grade 12, and disappointing across all grade levels for nearly 30 years (U.S. Department of Education, 2000a, 2006b).

From an international perspective, the Trends in International Mathematics and Science Study (TIMSS), developed and administered by International Association for the Evaluation of Educational Achievement, gathers student assessment data from dozens of nations and seeks to broadly compare student performance in mathematics and science in grades 4 and 8, evaluating both content and cognitive ability in science (U.S. Department of Education, et al., 2008). The most recent 2007 TIMSS data compared results from over 36 countries at the fourth-grade level and 48 countries at the eighth-grade level and found that the United States shows no significant differences over the 1995 rankings across both grades. From a benchmarking perspective, compared against the 19 other countries that participated in the previous 1995 TIMSS, the United States has shown zero growth, while at the eighth-grade level five other nations demonstrated improvement. The United States ranked 11th behind Singapore, Chinese Taipei, Japan, Korea, England, Hungary, Czech Republic, Slovenia, Hong Kong, and the Russian Federation respectively, when comparing the overall ranking averages of student scores for eighth-grade science, with 10 of these nations having significantly higher scores. For fourth grade the United States ranked 8th overall in science. But all is not without hope. Both the fourth- and eighth-grade rankings are above the TIMSS overall average score of 500, and from a statistical standpoint only four nations did significantly better than the United States in the 2007 results for grade four (U.S. Department of Education, et al., 2008). Unfortunately, this single glimmering statistic does not outshine the otherwise less-than-stellar results that are corroborated on other international measures as well.

Results collected in 2006 by the Organization for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) instrument across 57 nations and 400,000 randomly sampled students focused on science content,

specifically within the domain of science. The 2006 international assessment sought to evaluate 15-year-olds' ability to not just recall or recognize scientific theories and facts, but through open-constructed responses, evaluate students' ability to apply conceptual understanding and skills that should be part of all scientifically literate citizen's repertoire as they make informed decisions concerning science that is relevant to their lives (Bybee, 2008; Organization for Economic Co-operation and Development, 2007). It reported that the United States ranked below the top 20 countries from among the 57 nations participating in the study (i.e., the United States ranked 29 out of 57), and scored below the overall PISA average for student performance at a significant level (Organization for Economic Co-operation and Development, 2007).

Thus, across all these data, it would seem safe to say there is room for improvement. This brief comparison of student science achievement is warranted as it provides a window into the impact of classroom instructional practice, which ultimately, as many researchers now agree, is significantly linked to teacher quality as defined by teachers' knowledge and ability to apply subject matter and pedagogical content knowledge related to the subjects they teach (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000; Clermont & Borko, 1994; Council of Chief State School Officers, 2007a; Darling-Hammond, 2006; Economic Policy Institute, 2003; Goldhaber, 2002; Goldhaber & Brewer, 1998; O. Lee, 1995; Mestre & Cocking, 2002; Monk, 1994; Mundry, 2005; National Center for Research on Teacher Education, 1990; National Commission on Teaching and America's Future, 1996; Weinburgh, Smith, & Clark, 2008; Whitehurst, 2002; Wilson, Floden, & Ferrini-Mundy, 2002). National education reform efforts and legislation recognize the importance of high-quality teachers and provide significant funding and professional development program initiatives to support teachers' ongoing and continued growth upon entering the teaching profession ("America Competes Act ", 2007; National Academy of

Sciences, National Academy of Engineering, & Academies, 2007; National Staff Development Council, 2008; No Child Left Behind Act ", 2001; Sherwood & Hanson, 2008). Unfortunately, there appears to be a lack of coherence between the policy focus and results as reflected in student science achievement, and as such, urgency among researchers is placing an increased focus on teacher improvement (National Academy of Sciences, et al., 2007; U.S. Department of Education, 2000a). Could teachers' content knowledge (e.g., subject matter knowledge and pedagogical content knowledge) in part be responsible for the plateau in our country's student achievement?

Importance of Teacher Content Knowledge

As Lee S. Shulman originally posited over 30 years ago (1986), teachers need to have an understanding of the subject matter they teach, which as elaborated by Grossman, Wilson, and Shulman (1989), falls into three categories: (a) content knowledge (e.g., understanding of concepts, facts, and principles), (b) substantive knowledge (e.g., structure and conceptual framework how concepts and topics are organized), and (c) syntactic knowledge (e.g., canonical rules and processes by which knowledge in the discipline is formed). If elementary teachers charged with teaching science do not have understanding in these areas and their conception and beliefs concerning the nature of science is poor, research has shown significant and potentially negative impacts to their teaching in the following ways: (a) avoidance of teaching science altogether; (b) limiting time, structure, discourse, and topics selected for learning; (c) use of instructional strategies and questions that may limit and fail to formatively assess and build upon students' ideas to facilitate conceptual understanding; (d) failure to inculcate an understanding about the dynamic nature of science; and (e) facilitation of erroneous content knowledge and

misconceptions in the students they are charged to teach (Abell, 2007; Abell & Smith, 1994; Appleton, 2007; Butts, Hoffman, & Anderson, 1993; W. Carlsen, 1997; W. S. Carlsen, 1992; Garbett, 2003; Griffith, 2008; Grossman, et al., 1989; Harlen, 1997; Hashweh, 1996; Heywood, 2007; Howitt, 2007; Kang, 2007; C. A. Lee & Houseal, 2003; O. Lee, 1995; National Center for Research on Teacher Education, 1990; Parker, 2004; Schmidt & Buchman, 1983; Wilson, et al., 2002). It would seem from the literature above that a lack of science content knowledge for teachers—when not part of a coherent conceptual framework—may limit teachers’ ability to effectively plan and deliver instruction, which in turn may facilitate inert knowledge acquisition in their students as they wrestle with discrete sets of isolated facts and fail to gain an appreciation for the nature of science and inquiry that facilitates understanding of the concepts in question (Bransford, et al., 2000; Clermont & Borko, 1994; Desimone, Smith, & Ueno, 2006; Fishman, Marx, Best, & Tal, 2003; Garbett, 2003; Hanuscin & Lee, 2008; Heywood, 2007; Luera, 2005; Mundry, 2005; National Center for Research on Teacher Education, 1990; Weinburgh, et al., 2008). Thus it is not only knowledge of subject matter, but also knowledge of the pedagogical implications for how to teach it as well.

Pedagogical content knowledge deals with teachers’ understanding of particular subjects and concept instructional strategies that facilitate student learning in specific grade and content domains, taking into account knowledge of how students learn and as well as an awareness of particular topics that may be more challenging for student understanding (Abell, 2007; Bransford, et al., 2000; Hennessey, 1999; Magnusson, Krajcik, & Borko, 1999). Abell’s (2007) review states that while the conceptual change research has evolved with more constructivist sentimentalities, “overall, it appears that teachers lack knowledge of student science conceptions, but that knowledge improves with teaching experience” (p. 1128). As constructivist theorists

espouse, students come to formal learning with existing understandings as they make sense of the world around them on both a personal and social level (Piaget, 1978; Rogoff, 1990; Von Glasersfeld, 1989; Vygotsky, 1986). This is especially important at the elementary and middle levels where foundational science concepts are first introduced seeking to build on students' existing conceptions about the world in which they live (National Research Council, 1996; Science., 1993).

Elementary and Middle Level Teachers' Content Knowledge

A recent National Science Foundation–sponsored national survey of over 5,700 science and mathematics educators seeking to enumerate trends in teacher experience and background found that 71% of elementary teachers in self-contained classrooms (grades K–4), and 67% of middle level teachers (grades 5–8) reported the “need to deepen their own science content knowledge” (75% response rate) (Horizons Research, 2001, p. 37). With regards to teacher preparation, Horizon Research (2001) used proxy measures of degree major and number of courses taken within a field to gain insight into teachers' understandings in science and found that approximately 80% of grades K–4 teachers majored in elementary education. While this was anticipated, interestingly, 74% of middle level educators (grades 5–8) also majored in fields other than science or science education (e.g., general education) (Horizons Research, 2001). Similarly, an analysis conducted using more recent results from the National Center for Education Statistics 2004 Schools and Staffing Survey found that over 50% of upper elementary teachers in grades 5–6 are teaching in self-contained classrooms and are responsible for all core subjects, of which science is one, but have little formal preparation in science (Council of Chief State School Officers, 2007a). These studies reveal a real need for science content and

pedagogical content knowledge at the elementary and middle school levels. Finally, regarding teacher self-confidence in how well teachers were prepared to teach science, the survey results showed that only 18–29% of K–4 teachers felt very well prepared to teach physical science, Earth science, and life science (Horizons Research, 2001). For middle level teachers (grades 5–8) self-report data indicated teachers were more confident in their ability to teach inquiry process skills and Earth and space science, environmental science, and biology, but had lower confidence in physical science and chemistry (Horizons Research, 2001). In the 2000 National Survey of Science and Mathematics Education involving 31 randomly sampled sites, observers found that only one-third of the lessons were likely to have a beneficial effect on students’ understanding of the science concepts targeted within the lessons, with only 14% deemed of “high quality,” and 10% to 20% were observed to have a negative effect on student content understanding (Banilower, et al., 2006). Taken collectively, nationally sampled data of our nations’ teachers in grades three – eight seem to indicate that substantive numbers of teachers: (a) lack formal preservice training in science content knowledge, (b) lack confidence in their abilities to teach science and implement high-quality lessons, and (c) request the need to deepen their understanding of science content as a high priority for professional development. Thus, the need for high-impact professional development to address these issues is paramount.

Inadequate Teacher Professional Development to Address Need

From the large-scale reviews of experimental, quasi-experimental, and teacher self-report studies, it appears effective professional development (PD) needs to be of sufficient intensity and duration to produce change in teacher practice regarding integration of reform-based curriculum. Researchers suggest at least 49 to 80 hours of PD over the course of a school year; the PD should

not be administered as a single “one-shot” experience but instead it should be linked to authentic classroom instruction (Banilower, et al., 2007; Garet, et al., 2001; Supovitz & Turner, 2000; K. S. Yoon, et al., 2008). One of the biggest challenges for effective PD is providing sufficient time for teachers to reflect, discuss, create, analyze, and plan both individually and with colleagues to craft improvements in instruction based on student work and student assessment data (Fullan, 2007; Fullan & Miles, 1992; National Staff Development Council, 2008; Penuel, et al., 2007; Penuel & Means, 2004; WestEd, 2000). When one juxtaposes the total hours of PD completed against the large-scale survey data discussing the amount of time teachers receive for PD over the course of a school year, one begins to see the challenge in administering effective PD solutions. A review of the 2003–2004 federal Schools and Staffing survey, conducted by the National Center for Education Statistics, found that 57% of all teachers received less than 16 hours of professional development during the prior school year, and only 23% received more than 33 hours of PD over the same time period (National Staff Development Council, 2008). Research suggests a threshold of at least 30 hours of PD to effect change in teachers’ classroom practices (US Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, & Regional Educational Laboratory Southwest, 2007), with significant results occurring after 49–80 hours (Banilower, et al., 2007; Supovitz & Turner, 2000; K. S. Yoon, et al., 2008). Given this deficit, we are already failing to empower our teachers with adequate opportunities to make substantive changes in their classroom practice.

Focus Professional Development on Science Content Knowledge

While opinion on frequency, duration, and other features of “effective” professional development solidifies, the research supporting this consensus is not yet definitive (Banilower, et

al., 2007; Guskey, 2003; Wayne, Yoon, Zhu, Cronen, & Garet, 2008). As some researchers aptly convey, the sociocultural context of schools is extremely diverse, complex, and interconnected in many ways, thus making causal relationships between the effects of professional development and student achievement an arduous task (Clarke & Hollingsworth, 2002; Guskey, 2003; Hewson, 2007). The need for high-quality professional development is great—the approximately 1.9 million elementary teachers of science in the United States need support in their science knowledge and skills (Aud, et al., 2010; U.S. Department of Education & National Center for Education Statistics, 2009).

Research suggests PD that targets increasing teachers' science content knowledge and pedagogical content knowledge improves student learning, rather than PD that focuses on generic pedagogy or teacher classroom behavior strategies (Council of Chief State School Officers, 2008; Garet, et al., 2001; Heywood, 2007; Kennedy, 1998; Parker, 2004; Penuel, et al., 2007; U.S. Department of Education, 2000b). The link between teachers' knowledge of science content and pedagogical content knowledge as subject matter for effective professional development in K–8 science education is strongly supported in literature regarding conceptual change, science education, and how students learn (Appleton, 2007; Bransford, et al., 2000; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Driver, Guesne, & Tiberghien, 2000a, 2000b; Feiman-Nemser, 2001; Heywood, 2007; Monk, 1994; Posner, Strike, Hewson, & Gertzog, 1982; RMC Research Corporation & Center on Instruction, 2008). Teachers' abilities to effectively plan and facilitate students' construction of knowledge about the world around them is intimately tied to (a) teachers' deep understanding of the science content; (b) awareness of common challenges students may encounter in dealing with science phenomenon; and (c) knowledge of strategies, representations, and models that might be used to bridge the gap between students'

existing knowledge and that under instruction (Bransford, et al., 2000; Brown, 1992; Brown & Clement, 1989; Feiman-Nemser, 2001; Luera, 2005). This said, sensitivity in the degree and complexity of science content knowledge elementary teachers should know is warranted, as elementary teachers are generalists and responsible for teaching a wide range of subjects (Heywood, 2007; Luera, 2005; Parker, 2004).

Despite the insufficient hours of overall PD provided for teachers, the emphasis on content knowledge and how to teach it appears to be focused correctly, with 83.4% of teachers reporting their PD targeted how to teach specific content over the 2003–2004 school year, which is also corroborated with 23% of all teachers requesting content-related PD as the number one priority for their professional development (National Staff Development Council, 2008). Thus, professional development for elementary science teachers that facilitates a deeper understanding of science content within a conceptual framework using inquiry-centric pedagogy would seem worthwhile; research supports this as an effective means to learn the science content for prospective elementary teachers (Hanuscin & Lee, 2008). As Howes (2002) states:

Understanding scientific concepts and understanding scientific practices as socially constructed do not take precedence one over the other, nor do they follow each other in a linear sequence. They are instead thoroughly intertwined and challenge teachers to develop not only science content knowledge but knowledge of the role of science in our society, and knowledge of the children and communities whom we serve. (2002, p. 864)

For teachers in grades three – eight the question becomes what models are viable to address the scale necessary at a national level? How might we improve teachers' content knowledge through electronic professional development to reach all of our nation's teachers? When one looks at the financial investment of large-scale face-to-face PD models and the

numbers of teachers affected as compared to the number that need to be reached, face-to-face models alone do not appear to be either scalable or sustainable on a national level.

Online Teacher PD: A Complement to Face-to-Face PD

In a recent evaluation report sharing the makeup of professional development offerings of the 2005–2006 U.S. Department of Education Mathematics and Science Partnerships, 65% of these programs took the form of summer institutes with face-to-face follow-up during the school year (U.S. Department of Education, 2006a). The remaining 34% of the sponsored PD programs did not provide a summer institute, but instead provided on-site professional development, study groups, university courses, as well as online coursework and digital learning networks; however, the statistics for the proportion of each component were not disaggregated. In looking at the investment for the 2005–2006 school years, \$337,015 was the average expended per program, with a mean of 113 teachers attending each program. For a total investment of \$181 million, roughly 56,000 teachers were affected across 501 programs. While this figure appears substantial, considering there are over 3 million teachers of science in the United States (U.S. Department of Education & National Center for Education Statistics, 2009), it would take more than half a century to reach them via this approach. Looking at the magnitude of the average investment per program coupled with the average number of teachers served per program, it would seem that an online component may be more cost-effective. Couple these data with the fact that gross expenditures on professional development were approximately \$1.5 billion for the 2004–2005 school calendar year (American Institutes for Research & RAND Corporation, 2007) and that numerous PD offerings are now appearing online, the imperative to research the effectiveness and efficiency of current and future professional development models is axiomatic

(Dede, 2006; Dede, Ketelhut, Whitehouse, Briet, & McCloskey, 2009). As Dede (2006) states in his review concerning the importance for research in online professional development:

Currently many initiatives in online teacher professional development are serving large numbers of educators. However, while such programs are propagating rapidly and consuming substantial resources both fiscally and logistically, little is known about best practices for the design and implementation of these alternative models for professional enhancement. Evidence of effectiveness is generally lacking, anecdotal, or based on participant surveys completed immediately after learning experiences, rather than later when a better sense of long-range impact is attainable. (2006, p. 2)

Concomitantly, in keeping with current theories about the nature of high-quality PD—that it should be ongoing, locally based, and continuous throughout the school year (Elmore, 2004; Hawley & Valli, 1999; Loucks-Horsley, 1999; National Staff Development Council, 2008)—online learning opportunities may facilitate issues of scale, continuous support, and sustainability, therefore precipitating the need for research evaluating efficient models.

Major Supporting Theory

The intent of this quantitative study is to determine which features of on-demand, self-paced online professional development are most desirable and provide the greatest learning potential for upper level (grades three – six) elementary teachers. Anderson’s 2003 Equivalency of Interaction Theorem will be used, which states that if one of the following three levels of interaction in online learning is rich, the other two may exist in a diminished capacity: (a) learner-learner, (b) learner-instructor, and (c) learner-content. While other research has examined the extent and importance of social interactivity in asynchronous online university courses for

community college learners focused primarily on learner-learner and learner-instructor interaction through a constructivist lens (Farahani, 2003), this study will examine learner-content interaction for on-demand, self-directed electronic professional development modules for upper elementary educators using Anderson's Equivalency of Interaction as the undergirding theory for interactivity.

Anderson's Equivalency of Interaction Theorem states:

Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student-teacher; student-student; student-content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience. High levels of more than one of these three modes will likely provide a more satisfying educational experience, though these experiences may not be as cost or time effective as less interactive learning sequences. (p. 4)

See [Figure 1](#) for a graphic depiction of the three different types of interaction. The independent study quadrant will be examined as part of this study focusing on learner-content interaction and explored via different types of online interactivity with the content.

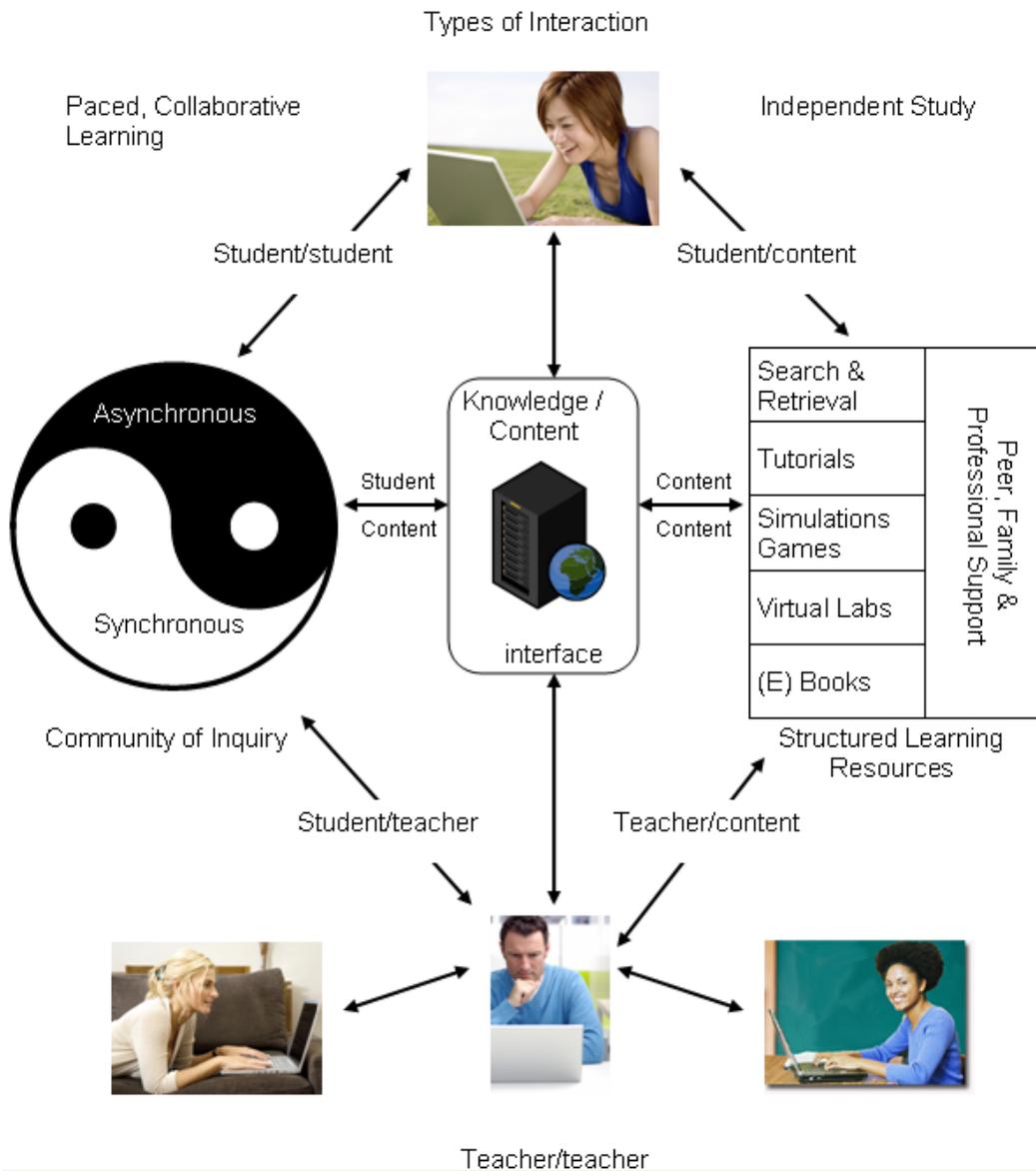


Figure 1. A model of online learning. As depicted in Anderson, T. (2003). Getting the mix right again: An updated and theoretical rationale for interaction. International Review of Research in Open and Distance Learning, 4(2). Retrieved from <http://www.irrodl.org/index.php/irrodl/article/view/149/708>, 2010, Used under fair use, creative commons license.

In Farahani's (2003) research she posited the importance of online interactivity that may be facilitated by constructivist learning principles leveraging the types of communicative discourse permitted via online moderated course environments, and evaluated their perceived importance by instructors and learners analyzing features of interaction such as (a) student discussion boards, (b) instructor feedback via email on student work, (c) peer feedback between individual students via email, and (d) collaborative group projects. Farahani used Salmon's (2001) five-step model for online learning to determine the availability and importance of various degrees of social interaction throughout the life cycle of an online course. Her study sought to explore the criticality of "virtual human interaction" (2003, p. 6) as part of the course design and online learning environment that ultimately seeks to develop a community of learners through the co-construction of knowledge via different methods of discourse and collaboration. Salmon's model (2001) expects different levels of intensity throughout the course and posited different e-moderator instructor techniques to garner higher student satisfaction and participation. Farahani developed two surveys (one for students and one for instructors) to analyze the different levels of social interaction available and employed a learner preference inventory developed by Neil Fleming called VARK (an acronym for Visual, Aural, Read/Write, and Kinesthetic). Unfortunately, while a review of the literature does show use of the sensory-based VARK inventory in other studies—such as for a 228 dental student sample taking "on-campus" courses (Murphy, Gray, Straja, & Bogert, 2004) and 288 undergraduate students across two CD-ROM hybrid courses in government and human development (Sankey, 2005)—a review of the VARK website supporting the instrument reports that reliability and validity statistics for the instrument do not exist, and that currently it is not recommended for statistical research (Fleming, 2001). Thus, while the value of examining learning preferences can inform future

development and decision makers regarding the type and worth of effective online PD for their educators, another inventory for consideration that does have validity and reliability studies to support its credibility is Kolb's Learning Style Inventory (LSI-3) (A. Y. Kolb & Kolb, 2005; D. A. Kolb, 1999), which will be explored in more detail in the methods and instruments section of this proposal.

While Farahani was looking to fill the gap in research in distance education concerning the importance of online social interaction between learner-learner and learner-instructor, this study will focus on the perceived importance of different types of content interactions available and their impact on learning outcomes as measured via a pre- and postassessment instrument aligned with the course content and teacher learner preferences. In Farahani's call for future research, she suggested that one area of consideration should be the comparative analysis of students' perceptions in online "classes with and without [social] interaction" (2003, p. 121). This study focused on an area that is of current interest in the literature: learner-content interaction for self-paced on-demand professional development (Krall, Straley, Shafer, & Osborn, 2009; Lapointe & Reisetter, 2008; Rhode, 2009; Schaller, Borun, Allison-Bunnell, & Chambers, 2007). It also explored Anderson's 2003 Equivalency of Interaction Theorem arguing that learner-learner and learner-instructor interaction may be diminished if learner-content interaction is high. A brief look at Anderson's theory is warranted.

Despite a long history of formal definitions of various types of interaction in distance education, Anderson claims "it still remains a challenge to define when an interaction has pedagogical or educational value," and the quality and value related to learning vary qualitatively among the affordances available (2003, p. 2). Drawing from research, Anderson argues that because of the increasing potential in (a) computational power, (b) networking capacity, and (c)

technological improvements, there is both the opportunity and the pressure to explore enhanced forms of student-content interaction as transformations from learner-learner and learner-instructor interactions. Most in distance education would agree that no single form of media, instructional method, or delivery mode is more advantageous than another, and that it is more about the alignment and availability between the three based on the desired learning outcomes, learner preferences, funding available, etc. (T. Anderson, 2003; Head, Lockee, & Oliver, 2002; Lockee, Moore, & Burton, 2002; Mentis, 2008). Anderson claims that a broad range and combination of delivery modes and pacing opportunities should be available for learners. For student-student interaction Anderson diminishes its import if the learning design is based more on cognitive or behaviorist learning theory approaches rather than constructivism, and suggests that some student-teacher interactions may be automated or substituted through content interactions such as virtual labs, teacher videos, or personalized frequently asked questions (FAQs). With respect to learner-instructor interaction Anderson (2003) claims in part that this type of interaction is usually the most difficult to scale in large mass education systems, and as such, is substituted with learner-content interaction. Similarly, some of this interaction “can be transformed into learning objects (video, animations, assessment programs, etc.), thus migrating student-teacher interaction to student-content interaction” (Anderson, 2003, p. 5).

Finally, Anderson says that learner-content interaction depends in part on the value of the content in its ability to engage learners in ways that facilitate knowledge construction and an existing relationship “between the capacity for interaction and resulting engagement, mindfulness, and motivation” on the part of the learner (2003, p. 6). Anderson acknowledges that independent self-paced online study materials have been recently enhanced through the addition of automated testing and quizzes, simulations, and learning objects that if designed properly,

may enhance the learning experience whereby minimal interaction is required with other students or the instructor. This theory is supported by others in the online science education PD literature who also suggest that the use of learning objects, simulations, and web modules are a rich area for study (Asbell-Clarke & Rowe, 2007; Sherman, Byers, & Rapp, 2008; Walker, Downey, & Sorensen, 2008), and others who posit on-demand, self-paced learning may be a viable alternative for certain adult learners juggling the hectic schedule of family, full-time careers, and online study, who may not need or see the worth of learner-learner interaction (del Valle & Duffy, 2009; Jiang, Parent, & Easmond, 2006; Lapointe & Reisetter, 2008; Rhode, 2009; Su, Bonk, Magjuka, Liu, & Lee, 2005). Ultimately, the model Anderson purports permits the exploration of one of the three areas of interaction that may address the scale and sustainability for large numbers of learners while also providing maximum flexibility for the learner (2003). A brief look at the research exploring the preferences, impact, and learner demographics across the three types of learner-content, learner-learner, and learner-instructor interaction will inform the variables for analysis in this study.

Learner-Instructor, Learner-Content, and Learner-Learner Studies

A study by Russell, Kleiman, Cary, and Douglas (2009) suggests that little research has examined specific online professional development formats and their impact on teacher practice and student learning, stating that many recommendations lack a base in solid experimental research. Their 2008 study found that middle level teachers (grades 5–8) participating in self-paced online mathematics PD that provided no learner-learner interaction had similar effective learning outcomes as those teachers who also received moderated online PD involving facilitators and learner-learner interaction (Cary, Kleiman, Russell, Douglas Venable, & Louie,

2008). The 2009 Russell et al. study sought to determine the different impacts for 145 middle school algebra school teachers receiving an 8-week online professional development experience that had varying levels of support and social facilitation across the following treatments: (a) a highly supported condition that included an instructor, facilitator, and peer-peer interaction; (b) a moderately supported condition that included a facilitator and peer-peer interaction, but no instructor; (c) a moderately supported condition that included an instructor and facilitator, but no peer-peer interaction; and (d) a self-paced condition with no support available. Six instruments were used that collected data on teachers: (a) a demographic background survey and technology acumen, (b) closed-ended pedagogical beliefs and instructional practices survey, (c) pre- and postpedagogical and content knowledge assessment, (d) two pre- and postweekly teacher logs to identify implementation of instructional practices, (e) a student survey to triangulate findings from the pedagogical beliefs survey and teacher logs, and (f) a course evaluation to evaluate all components of the online course. Interestingly, 46% dropped out of the course, even with a \$200 course completion incentive, with the highest dropout rate (53%) coming from the highly supported group. The nonsupport group had the second lowest dropout rate at 44%. Teachers who reported they were (a) certified to teach mathematics, (b) majored or minored in mathematics, or (c) frequent users of computers were more likely to complete the course. For the three support levels that provided learner-learner interaction via discussion boards, the study showed they were used often and the large majority of postings were tied to course content. While significant differences were found in both the pre- and postpedagogical surveys and the pre- and postcontent assessments after the treatments were administered, there were no significant differences between the different treatment groups, thus showing that while online mathematics PD was effective at changing teachers' pedagogical beliefs and content knowledge,

the instruments observing the differences between the groups were either not sensitive enough to detect significant differences, or the differences were nonexistent in the design methodology employed. In either instance, we cannot say that the different support levels were equally effective (Lockee, Burton, & Cross, 1999), and the study failed to lend insight into what features in the self-paced, nonsupport component (i.e., the component with no learner-learner or learner-instructor interaction), were of most value to learners.

In a recent mixed method study seeking to determine what forms of interaction adults most desire in self-paced online courses, Rhode (2009) employed a convenience sample of 10 adults who were fully enrolled in an online 1-year PD certificate program in a private university in the northeastern part of the United States. Triangulating self-reported frequencies of content-interaction availability against learner interview transcripts and member checks for accuracy, the study found the following: (a) participants expressed a strong satisfaction with the course activities, varied multimedia, and self-paced structure of the course; (b) participants self-reported engagement most frequently with the course content or course instructor over learner-learner interaction; (c) participants consistently ranked components involving interactions with other learners as lowest in comparison to learner-instructor and learner-content interaction opportunities; and (d) narrative interview responses validated the quantitatively ranked interaction preferences, with web 2.0 tools such as blogging and social bookmarking as worthwhile activities to foster learning (Rhode, 2009). From 30 different elements and pedagogies offered in the self-paced course, adults ranked the following forms of interaction most valuable: (a) application of assignments, (b) communications from instructor, (c) instructional presentations, and (d) external resources, with all of the top 10 elements involving interactions with either the content or the instructor. This study, while limited in its external

generalizability, demonstrates that for some adult learners, not all forms of interaction as defined by Anderson (2003) are equally valued, and some activities, such as individual informal blogging, may in some ways be more desirable than instructor-directed asynchronous discussion boards. It supports the Theory of Cooperative Freedom, which argues that many learners in distance education environments not only choose the format they desire, but search for the freedom to also control the time, place, pace, media, and curriculum content they desire as adult learners (Paulsen, 1993).

In another study that sought to understand students' perceptions of online learning communities (i.e., learner-learner and learner-instructor interaction) and involved 74 graduate students enrolled in a masters program, students experienced significantly more interaction with their online instructor versus their online peers (Lapointe & Reisetter, 2008). A Likert scale survey and open responses revealed that many participants valued the interaction with their instructors significantly more than their peers (whether required or voluntary), and some found the learner-learner interactions to be superfluous, inconvenient, and not supportive of their online learning processes. While some expressed the virtual community as helpful to their learning, the feedback was mixed. Some participants did not like online learning, some liked online learning with peer interaction, and others preferred self-regulated, independent learning; the largest value appeared to be the flexibility of the environment (Lapointe & Reisetter, 2008). To help support the need for this study and explain, in part, its findings, the Self-Determination Theory (SDT) was posited (Ryan & Deci, 2000). Given this study's implications for the research at hand, a brief review of SDT is warranted.

Ryan and Deci (2000) use SDT to help examine and understand the impact between social contexts and individuals' intrinsic and extrinsic motivation. They claim that if social

contexts are supportive of three basic psychological needs—competence, autonomy, and relatedness—the result leads to increased personal motivation, personal growth, and well-being; the opposite effect may also result, thwarting motivation if the social contexts negatively impact these three basic needs. *Competence* is one’s perceived ability to effectively execute a task or action. *Autonomy* is the degree of self-direction provided to the learner (from an education perspective), and *relatedness* describes the perceived degree of belongingness desired by the learner.

Understanding the social factors that affect motivation are important as Ryan and Deci (2000) cite research espousing the impact for learning, such as better performance, higher self-efficacy, increased engagement, and increased persistence for the activity at hand. SDT is not concerned with what causes motivation but assumes individuals are inherently and graciously endowed with “intrinsic motivational tendencies” (Ryan & Deci, 2000, p. 70). Instead, SDT seeks to provide insight into contextual factors affecting motivation and is divided into two subtheories: (a) Cognitive Evaluation Theory (CET), and (b) Organismic Integration Theory (OIT) (Ryan & Deci, 2000). CET focuses on intrinsic motivation (e.g., performing an activity for its inherent satisfaction) and argues that social-cultural events such as (a) effectance-promoting feedback, (b) optional challenges, and (c) avoidance of demeaning evaluative feedback increases an individual’s competence for the task at hand. CET argues that intrinsic motivation is elevated if an activity is perceived as autonomously self-determined (as opposed to externally controlled), and increased internal confidence occurs as a result of the learner’s experience. CET states that autonomy is positively affected by the degree of personal choice and self-direction permitted, which includes acknowledgment of feelings, and is negatively contrasted with external rewards, deadlines, or pressured evaluations. Ryan and Deci (2000) go on to clarify, “...within SDT,

autonomy refers not to being independent, detached, or selfish, but rather to the feeling of volition that can accompany any act, whether dependent or independent, collectivist, or individualist” (p. 74). Relatedness, the third basic psychological need, is described as one’s self of belonging, where Ryan and Deci (2000) reference educational studies demonstrating decreased internal student motivation when learners’ actions are ignored by instructors. They balance their perspective of social interaction with the caveat: “Of course, many intrinsically motivated behaviors are happily performed in isolation, suggesting that proximal relational supports may not be necessary for intrinsic motivation, but a secure relational base does seem to be important for the expression of intrinsic motivation to be in evidence” (Ryan & Deci, 2000, p. 71). While the CET subtheory of Self-Determination Theory argues that intrinsic motivation may be enhanced or hindered by social environments, Organismic Integration Theory (OIT), the second subtheory of SDT focuses on the social contextual factors that affect primarily extrinsic motivation.

OIT seeks to understand and explain how individuals’ extrinsically motivated behaviors may be internalized and integrated along a continuum from non–self-determined to completely self-determined behavior and posits individuals may move between amotivation, extrinsic motivation, and intrinsic motivation. Intrinsic motivation is on one end of the continuum and represents behavior that is highly autonomous and exemplifies self-determination that is intrinsically regulated by the individual. On the other end of the continuum is amotivation, where individuals’ behavior is non–self-determined and non–self-regulated (e.g., individuals place no value on the behavior, perceive no control in the action, lack confidence to execute the action, and may just go through the motions) (Ryan & Deci, 2000). Extrinsically motivated behaviors are subdivided into four regulatory styles: (a) external regulation, (b) introjected regulation, (c)

identified regulation, and (d) integrated regulation. The regulatory styles for extrinsic motivation vary from complete external control (e.g., rewards and punishments) to increasing degrees of internalization and integration of the externally regulated behavior or motivation. In integrated regulation individuals transform the externally perceived motivations into their own self-driven motivations and self-regulated actions. In closing, Self-Determination Theory seeks to understand and determine the social contexts that facilitate or inhibit internalization and integration of externally motivated behaviors. As intrinsic competence, autonomy, and relatedness are supported, Ryan and Deci posit that externally motivated behaviors may be internalized and integrated as emanating from self and increase learning effectiveness of the activity at hand (2000). Returning to the Lapoint and Reisetter (2008) research, their study appears to corroborate the further exploration of different types of learner-content interaction that may be perceived as worthwhile for the audience in question when learner-learner and learner-instructor interaction is omitted. When the interaction between learners and instructors is minimal, the focus on content interaction becomes the central core of study.

Several studies looked at how learners' preferences vary among different types of web-based activity. In a 2002 study Schaller, Allison-Bunnell, Borun, and Chambers used online exit surveys and web log statistics analyzing duration of stay across five activity sites and a comparison control site for self-selected subjects (N=250 and N=299 respectively). They looked at the following different types of online content interactivity: (a) creative play, (b) guided tour, (c) interactive reference, (d) puzzle/interactive mystery, (e) role-playing, and (f) simulation. Findings revealed clear differences between the types of web-based learning preferred among adults and children (Schaller, Allison-Bunnell, Borun, & Chambers, 2002). Adults favored interactive reference or simulation-based content while children preferred creative play or role-

playing, with the researchers positing that novice learners, irrespective of age, are more likely to prefer guided experiences if the content is new to them (Schaller, et al., 2002). This research is corroborated in part by later studies confirming the value adults express in learning via simulations (Sherman, et al., 2008).

Later, National Science Foundation–sponsored research by Schaller et al. (2007) used Kolb’s Learning Style Inventory 3.1 (2005; 1999) to explore the effects of learning style, age, and gender on user preferences for web-based learning with an updated classification scheme for content-interaction (i.e., role-play, simulation, puzzle-mystery, interactive reference, discussion forum, and design). The researchers found that “learning style does influence an individual’s preferences for learning activities, particularly among adults,” with adult social learners (i.e., Kolb accommodating learning style) preferring role-play while reference style content was preferred by intellectual learners (i.e., Kolb assimilating learning style) (Schaller, et al., 2007). Two separate online exit surveys posted on more than 11 museum websites collected data from over 5,600 respondents (including more than 2,200 adults) across both surveys and found a difference between the collective learning styles of adults as compared to students between 10 and 13 years old. Children preferred role-play and design web activities, while adults preferred interactive reference and puzzle/mystery (Schaller, et al., 2007). Gender was subservient to age in weighting student versus adult preferences to learner-content interaction types, but when comparing only boys to girls at ages 10–13, gender did reveal significant different preferences in interaction types, thus demonstrating the importance of designing web-based activities for intended audiences. The researchers found that adult creative learners (Kolb diverging learning style) preferred discussion and social learners (Kolb accommodating learning style) preferred design activities, both contrary to researchers’ hypotheses. Three of Schaller et al.’s (2007) predictions were confirmed: (a) intellectual adults (Kolb assimilating learning style) prefer interactive reference, (b) social adults (Kolb accommodating learning style) prefer role-play, and (c) practical adults (Kolb converging learning style) prefer puzzle/mystery. The Schaller et al. study (2007) did not look within adult ages for differentiation, but only compared the adults to

children 10–13 years old. Given this overall review of different online interaction strategies from the literature, a more detailed review will now examine specific independent and dependent variables related to learner-content interaction.

Research Pertaining to Independent Variables

In a study looking at the relationship between content usage, age, and work experience involving 59 inservice teachers, 24 of whom worked at the elementary level, del Valle and Duffy (2009) used a cluster analysis to study the usage patterns and learning strategies applied by learners in on-demand courses focused on inquiry-based teaching practices and technology integration that were part of a 60-course repository with one-on-one email mentoring. Through the use of complex log files (click-stream data) that leave “footprints” of user activity, del Valle and Duffy (2009) revealed three clusters of users: (a) mastery oriented or “self-driven,” (b) task focused or “get it done,” and (c) minimalist in effort or “procrastinator” (pp. 139–141). Mastery-oriented users (the largest cluster in the study at 59.3%) had far more sessions working across longer periods of time within the 12-week allotment, while task-focused users (comprising 22% of the sample) progressed through the courses in significantly shorter time frames (i.e., 3 weeks on average) with more frequent logins, and the minimalist group (making up 18.7% of the sample) used the longest period overall to complete the course with the fewest logins and shortest time online (del Valle & Duffy, 2009). All participant clusters rated their feedback across the three dimensions high with no significant difference between any of the following three areas: (a) perceived ability to transfer the knowledge from the course, (b) satisfaction with the course, and (c) self-reported learning from the course. Using separate one-way ANOVAs of teaching experience and age, del Valle and Duffy (2009) did report two significant difference

findings: (a) the minimalist cluster preferred to learn via cohort approach, and (b) the mastery-oriented group had significantly more years teaching experience than the task-focused group. Age was not found to be a significant difference among the three clusters. These findings differ from prior research that used brief clinical trials assigning search-oriented tasks versus this study, which used an extended time frame in the context of authentic ongoing learning tasks. Also different in this study: learners voluntarily selected courses of interest to them, and the largest study group did not comprise those classified as minimalists, but those with a mastery level of experience (del Valle & Duffy, 2009). Final suggestions included additional scaffolding for the minimalist learner and limitations of the study using self-report data looking only at online activity (del Valle & Duffy, 2009). Interestingly, other studies focusing on self-directed learner engagement in online professional development tend to find similar patterns, lending credence to the relationship between teachers' preferences for learning and their anticipated engagement levels online (Whitaker, Kinzie, Kraft-Sayre, Mashburn, & Pianta, 2007; Yang & Liu, 2004).

Similarly, Hoskins and van Hoof (2005) examined the relationship between the independent variables of gender, age, prior academic ability, and approaches to studying as related to learner motivation and achievement for 110 undergraduate students taking a 12-week biological psychology course with an online component using WebCT. They analyzed the utilization level of online tools for learning (e.g., online quizzes, personal self-assessments, discussion boards, etc.). Multiple linear regressions analyzed relationships between gender, age, prior academic ability, and study approach, while analysis of covariance determined whether web use influenced academic achievement. In comparing overall number of web hits, period of access, and bulletin board use in this blended course, the analysis of variance revealed no main effects on overall achievement as measured via a 35 multiple-choice question exam, or student-

generated reports contributing to the same. Hoskins and van Hoof (2005) did find that students greater than 21 years old were more likely to put forth additional effort to process content learning at a deeper level and were more likely to learn for intrinsic reasons. As age increased, so did number of logins and the period of time spent online. Also, students of lower achievement orientation that repeated an online quiz more often were more likely to show improvement in learning, and those that demonstrated higher achievement motivation made use of all online resources available (Hoskins & van Hooff, 2005). Age was also a predictor with respect to the degree of use of the online discussion board. As age increased for learners, so did their number of postings and readings; these researchers suppose that this may in part be due to the nature and motivation of the participants (their orientation to learning) rather than their age, positing that if “older adults are not disadvantaged by lack of general education, IT knowledge, and access to computers, they may be more active in their online learning than younger adults,” (Hoskins & van Hooff, 2005, p. 188).

Finally, those that were high achievers and more achievement oriented (as determined by a study orientation instrument) spent more time on the discussion boards. Hoskins and van Hoof (2005) submit several reasons for this phenomenon, such as (a) higher achievers are more organized and have more time to participate in online discussions, or (b) higher achievers are more adept at employing key learning strategies such as social constructivism for concept acquisition (Vygotsky, 1978). Caution should be noted in the findings as the sample was primarily women (85%), and the vast majority of 110 students participating in the study were younger than 22 years old with the 9 older students of the 110 falling in the following categories: (a) 24 years old ($n=1$), (b) 27 years old ($n=4$), (c) 30 years old ($n=1$), (d) 31 years old ($n=1$), (e) 35 years old ($n=1$), (f) 36 ($n=1$), and (g) 43 years old ($n=1$). The age range for all participants in

the study was from 19 to 43 years old with the mean age of 20 across all 110 participants. Hoskins and van Hoof (2005) close their study with a call to examine components in online learning environments in more detail and to explore the use of content and delivery styles in an effort to maximize student engagement and learning. Given the small sample of older learners, the authors conclude with a call for more research to confirm or refute the findings with a larger population of mature learners and “which manipulates whether or not the use of an online learning environment is assessed” (Hoskins & van Hooff, 2005, p. 190).

In another related study that confirmed the internal validity and reliability of the Kolb Learning Style Inventory 3.1 based on the Kolb (2005) Experiential Learning Cycle Theory, Kayes (2005) found significant differences in learning preferences between undergraduates and graduate students in business courses and argued this could be attributed to either differences in age or work experience. Finally, in a study analyzing if adult learners and children did indeed prefer online web-based informal learning activities that matched their learning preference using the Kolb Learning Style Inventory 3.1, Schaller et al. (2007), compared the independent variables of age, gender, and learning preference. Learning style and age (comparing adults to children, but not within age ranges of adults) were major factors affecting adult activity selection. Those classified under the Kolb assimilating learning style preferred interactive reference and simulation content, while those with accommodating preferences preferred role-play experiences (Schaller, et al., 2007). The study herein will build upon this research using similar labeling and chunking of online content interactivity (e.g., interactive reference, simulation), seeking relationships between the independent variables of age, years teaching experience, and learner preference. See [Appendix A](#) for additional literature on learning preference related to the Kolb LSI 3.1 (A. Y. Kolb & Kolb, 2005) that examined achievement

related to course delivery mode preference and learning style (Brittan-Powell, Legum, & Taylor, 2008).

With respect to looking at achievement in online learner-content interaction, in addition to the Hoskins and van Hoof (2005) study above, there have been several studies incorporating learning impact as a covariate of analysis (Krall, et al., 2009; Russell, et al., 2009; Sherman, et al., 2008). In a recent study that involved hands-on inquiry experiences as part of a 30–40 hour online moderated course in temperature and heat for 43 teachers in grades 4–8, Krall et al. (2009) found significant gains in content knowledge and conceptual understanding for 81.4% of the participants in six of the nine science concepts addressed in the course. In this study, materials kits were shipped to each participant, with the incentive of receiving a classroom set of materials if the course was completed. The use of kits for distributed PD has cost and logistical implications for scaling delivery if high volume is achieved. Although, others outside of the United States, such as the United Kingdom’s Open University, have demonstrated the capability to ship kits abroad on a large scale since the 1970s (Downing & Holtz, 2008). When asked to rank the importance of various components of the online course, 85% gave the highest priority to both interaction with other local teachers and the hands-on kit materials, while the lab activities and hands-on investigations to use the materials ranked second at 82%; the component that ranked third (68%) was the CD-ROM content to guide concept development (Krall, et al., 2009). Interaction with the instructor was ranked least important of all the components, and equal in perceived value to that of keeping a reflective journal at 54%. Caution should be applied in generalizing findings of Krall et al. (2009), as they did not have a control group or employ randomization in the selection of its participants across varied treatments.

Finally, in a three-district pilot study by the National Science Teachers Association in exploring the impact of on-demand, self-directed web modules in force and motion, 45 teachers from three districts participated, with two district models occurring entirely online, and a third incorporating interactive simulations as part of a blended solution that involved a one-day face-to-face workshop and two synchronous 1-hour web seminars (Sherman, et al., 2008). The study was a quasi-experimental pretest/posttest design using intact nonrandomized volunteer groups from each district, so generalizability is limited. Results show 91.1% of all participants completed all self-directed content available, which included passing the embedded final assessment with a score of 70% or higher. Analysis of the pre- and posttest results revealed significant gains in learning for teachers participating in the two “completely online” cohorts. The blended professional development model, which had the highest opportunity for contact hours did not show significant teacher gains in teacher content knowledge, with possible reasons cited for these findings. Thus with multiple studies looking at age, years teaching experience, or learning preferences related to online content delivery types and varied levels of support, as well as learning achievement related to self-directed online adult learning (Brittan-Powell, et al., 2008; Dede, et al., 2009; del Valle & Duffy, 2009; Hoskins & van Hooff, 2005; A. Y. Kolb & Kolb, 2005; Krall, et al., 2009; Schaller, et al., 2002; Schaller, et al., 2007; Sherman, et al., 2008; Whitaker, et al., 2007), it seems worthwhile to examine these variables to inform the design and selection of e-PD resources for elementary adult educators at a scale that is sustainable on a national level. See [Appendix B](#) for a brief overview of the literature in tabular format and explication of the dependent variables under examination that will follow.

Research Pertaining to Dependent Variables

Online learner-content interaction has been reviewed and analyzed in the literature (Harlen, 2004; Hoskins & van Hooff, 2005; Jiang, et al., 2006; Krall, et al., 2009; Rhode, 2009; Schaller, et al., 2002; Schaller, et al., 2007). For example, Rhode (2009) studied usage patterns of learners that were provided a rich mixture of media with asynchronous email mentoring and access to a wealth of collaborative group learning tools. Findings from this exploratory study of two undergraduate courses in educational technology revealed that interaction with the instructor and quality content were the highest ranked requirements, being rated more valuable than tools such as blogs, tagging resources, e-portfolios, and learner-driven communities (Rhode, 2009). The researcher reports these findings support that of others as to the importance of instructor and quality content in online learning (Dennen, Darabi, & Smith, 2007; Jiang, et al., 2006; Kupczynski, Brown, & Davis, 2008; Lapointe & Reisetter, 2008). Not all learners see the value of online communities (e.g., professional adult learners in graduate school) (Lapointe & Reisetter, 2008), or their need to participate heavily in them (Daugherty, Lee, Gangadharbatla, Kim, & Outhavong, 2005). This may corroborate the findings of del Valle and Duffy (2009) who describe learners as task focused, with little additional time to engage in dialog that at times may appear superficial (Lapointe & Reisetter, 2008) or is not considered high priority for certain adult learners (Su, et al., 2005). Given these data, this study will look at five different types of learner-content interaction that are drawn from the literature aligned with learner preferences (A. Y. Kolb & Kolb, 2005), web-based interaction types (Schaller, et al., 2002; Schaller, et al., 2007), and components showing promise in online science education and professional development (e.g., hands-on activities) (Harlen & Doubler, 2004; Krall, et al., 2009). Specifically, this study examined the five following content-interaction types: (a) interactive reference, (b) pedagogical

implications, (c) hands-on activities, (d) personalized feedback, and (e) simulations. [Appendix C](#) provides screen captures of each component as described below.

Simulations employ a high level of user control, where learners may change the parameters or values of variables within the simulation and see the resultant difference in observed phenomenon (e.g., height of object dropped, type of surface ball is rolling across, force applied to an object in motion, etc.). Simulations appear within the web module labeled as "click here to start interactive." Hands-on activities provide a description of a tangible activity the adult learner may engage with at home to help understand the science concept or phenomenon under examination. Typically, activities include a brief description of the procedure and materials that are readily accessible (not complex science chemicals or apparatus). Hands-on activities appear several times throughout the web module as a stand-alone box, with a pop-up window of the activity. Personalized feedback constitutes embedded questions that appear throughout the content and as a formative quiz at the end of each science topic (e.g., position and motion, Newton's first law, etc.). Questions may be multiple-choice single or multiple answer and involve interactivity such as drag and drop, hotspot identification, or sequencing of items in question. If users select a distractor, they are provided with rich, descriptive feedback. Questions contain hints and unique feedback based on challenges learners may be struggling with and in certain instances provide recommendations and URL links to re-review certain content or view new content if users exhaust the number of attempts for the question and fail to get the correct answer. The pedagogical implications component provides grade-band specific information tied to the particular science content topic area. This part of the web module is designed to help teachers recognize the level of sophistication appropriate for their students, identify or diagnose students' preconceptions, and employ strategies that are most effective for

the particular ideas they teach. It is not interactive with respect to embedded questions and simulations, but provides a visual map that shows the relationship between both the National Science Education Standards (National Research Council, 1996) and the Benchmarks for Scientific Literacy (Science., 1993) as well as the narrative, which is broken out by the following grade bands: K–2, 3–5, 6–8, 9–12. Table 1 provides an example of the frequency of different interaction types found within one web module.

Table 1
Overview of Learner-Content Interaction Strategies for Force and Motion Web Module

Learner-Content Interaction Type	Interactive Components within Content-Interaction Type	Number of Instances within web module
Interactive Reference	Audio component for playback (identical to text narrative, available on every page in web module)	63
	Picture slide-shows (click next, view images as answer question)	3
	Animations (user press play to view animation, may contain sound)	6
	Check your thinking/hint (question with mouse-over feedback)	22
	Glossary of terms in F&M SciPack (12 terms)	1
Simulations	Flash simulations (user makes selections/decisions within Flash, view results)	13
Personalized Feedback	Embedded questions throughout the content and quiz questions at the end of each topic within the web module (multiple choice, ordering, drag and drop, hotspot), no score presented, rich feedback after choices made	52
Hands-On Activities	Discrete hands-on activities embedded within module	8
Pedagogical Implications	Pedagogical Implications Component (broken out by grade level: K–2, 3–5, 6–8, 9–12). Suggests instructional strategies, known student preconceptions, and what is cognitively	1

Learner-Content Interaction Type	Interactive Components within Content-Interaction Type	Number of Instances within web module
	appropriate for students by grade band for science content areas (approximately 18 pages, 7,500 words)	

In summary, each web module is structured around an inquiry-based learning cycle (Bybee, 1997; Glasson & Lalik, 1993; National Research Council, 2000)—modified for adult learners in the online environment—that challenges teachers to struggle with questions, observations, and scientific phenomena, and apply their ideas. The design of simulations and animations are guided by research into cognitive load and the effective use of multimedia for instructional purposes (Bayraktar, 2001; Cameron, 2003; K. M. Lee, Nicoll, & Brooks, 2004; Mayer & Moreno, 2002; Reed & Jazo, 2002; Renkl & Atkinson, 2002; Schnotz & Rasch, 2005). A standardized development template draws from *Understanding by Design* (Wiggins & McTighe, 2005), and instructional systems design principles (Dick, Carey, & Carey, 2008; Sullivan & Higgins, 1983). Best practices in e-learning course design are applied to ensure that the pace, sequence, annotation, organization, and interactivity are compelling and effective (Hacker & Niederhauser, 2000; Horton, 2000; Moreno & Valdez, 2005; Rosenberg, 2001; Rossett, 2002; Simonson, 2000; Wallen, Plass, & Brunken, 2005), and the overall process incorporates iterative reviews by experts and end users during the formative stages (Tessmer, 1998) to ensure the learner-content interaction types are as effective as possible within the budget available for production. The production process and inquiry-based templates warrant several simulations, animations, and hands-on activities per 2-hour engagement, as well as embedded questions throughout the narrative, audio playback on every page, a five- to seven-

question quiz at the end of each content topic, a glossary for each web module, and a pedagogical implications component broken down by grade band (i.e., K–2, 3–5, 6–8, 9–12). This standardized production process and inquiry-based design template is available for review in [Appendix D](#).

As shown above, the individual components that comprise the web module are drawn directly from research in science education and the impact of simulations in learning science phenomenon are a major content delivery type (Bayraktar, 2001; Downing & Holtz, 2008). K–12 meta-analysis studies show simulations and computer-based instruction generally improve student learning at a significant level (small to moderate effect size), and increase attitudes toward learning and efficiency in learning (Bayraktar, 2001; Kulik, 1991; J. Lee, 1999; Vogel, et al., 2006). Others reviewing online PD courses in science comment on the lack of simulations and learning objects that might be used to enhance learning for educators in addition to rich facilitator-lead discussions (Asbell-Clarke & Rowe, 2007). Ultimately there appears to be an emerging consensus at the K–12 level in science that simulations and computer-based instruction enhance user motivation and learning when used by student learners (Kulik, 1991; Linn, Lee, Tinker, Husic, & Chiu, 2006; Lunetta, Hofstein, & Clough, 2007; Songer, 2007; Varma, Husic, & Linn, 2008; Vogel, et al., 2006; Zucker, Tinker, Staudt, Mansfield, & Metcalf, 2008). The way in which simulations are used makes a difference in their performance in students, with Lee (1999) finding simulations most effective with teacher guidance during presentation and practice, while others emphasize the importance of self-direction as necessary to increase learning outcomes (Vogel, et al., 2006). In both of these meta-analysis studies, researchers are confident in the trends reported, but caution readers in generalization of the findings given potential challenges of confounding variables across the multiple studies (J. Lee, 1999; Vogel, et al.,

2006). While simulations are now a mainstay of science education, they are only part of the learning content interaction landscape with hands-on learning a linchpin of science pedagogy.

With respect to hands-on professional development provided at a distance, two recent studies in the United States show promise (Harlen & Doubler, 2004; Krall, et al., 2009), coupling online discourse with hands-on investigation through the use of readily available household items (Downing & Holtz, 2008). In Harlen and Doubler (2004), 15 elementary and middle school teachers completing an online course in properties of matter and changes in matter demonstrated significant gains in science content knowledge through the use of hands-on inquiry-based learning that incorporated asynchronous discussion as participants shared predictions, procedures, results, and explanations of findings. When asked to rank their preference for the most important components of the online course, 7 teachers reported the use of inquiry as an instructional strategy most valuable, 5 cited the hands-on investigations as most important, 3 expressed the discussion with colleagues as most valuable, 2 preferred reflecting via an online journal, and 2 teachers ranked all components equally valuable (Harlen & Doubler, 2004). These results corroborate that of others who find that different types of learners have varied preferences for the features they feel most important when learning online (del Valle & Duffy, 2009; Navarro & Shoemaker, 1999; Rhode, 2009; Sherman, et al., 2008; Su, et al., 2005; Sujo de Montes, 2009; Yang & Liu, 2004). From this study it would seem that hands-on inquiry-based learning experiences may be enhanced through online delivery given Harlen et al. (2004) found online participants spending more time working on the course content. Krall et al. (2009) found similar positive adult learner preferences for hands-on activities that were one component of online PD discussed earlier in the literature review. Thus, hands-on activities are added as a learner-content interaction type given their importance in science education and online literature,

their inclusion in the web modules under examination, and the fact that they are clearly identified as a distinct learning preference in the Kolb LSI 3 (2005). In addition to simulations and hands-on learner-content interaction types, interactive reference has also been used from prior research studies.

Shaller et al. (2007) used the Kolb LSI 3.1 to analyze if adult learners and children did indeed prefer online web-based informal learning activities that matched their learning preference, also comparing the independent variables of age and gender. This study looked at the following web-based learner-content interaction types: (a) role-play, (b) simulation, (c) puzzle-mystery, (d) design, (e) interactive reference, and (f) discussion forum (Schaller, et al., 2007). Role-play was defined as permitting learners to interact with others via an adopted persona. Simulations allowed learners to manipulate variables in understanding a real-world, complex system. Puzzle-mystery involved deductive reasoning and evidence from people, nature, and reference material. Design involved open-ended experimentation and emphasized the personal creation of a product from the experience. Interactive reference provided multimedia content in a thematic topical structure for self-directed browsing, and discussion forums facilitated personal communication and feedback between learners and the instructor. The researchers predicted alignment of these learner-content interaction types with specific learning preferences from the Kolb LSI 3.1 (2005). Several hypotheses were verified matching content interactivity type with adult learning preference (i.e., interactive reference and puzzle-mystery) (Schaller, et al., 2007). This study was an extension of an earlier study by Schaller et al. (2002) that included the same learner-content interaction categories, with the exception of a translation from “creative play” to “design” content type in the later study, the removal of “guided tour” as a content type in the later study, and the omission of “discussion forums” as an interaction type in the earlier study.

For the study at hand, a direct alignment with the interaction content type of interactive reference is included, is consistent across both studies, exists in the web module under examination, and is identified with the assimilating learning style preference Kolb LSI 3.1 (2005).

Similarly, “discussion forums” and “role-play” interaction types are axiomatically omitted given this study will focus exclusively on learner-content interaction. With this omission noted, the science content web modules do include personal feedback from a learner-content only perspective, as defined by the diverging learning style preference and the Experiential Learning Theory (D. A. Kolb, 1984). The diverging style focuses on those who are interested in people, prefer to work in groups, and enjoy “receiving personalized feedback” (A. Y. Kolb & Kolb, 2005, p. 5). For the study at hand, the grouping of questions with individual feedback has been classified as “personal feedback” and has been hypothesized to support the learning preference by those categorized with a diverging learning style as the closest approximation with respect to learner-content only interaction. A similar argument for examining pedagogical implications exists looking across the literature in science education, online learning, and learning preferences.

Pedagogical implications, by the very nature of its content and its learner-content interaction type, appear to fall squarely in the converging learning style preference (A. Y. Kolb & Kolb, 2005). As stated in more detail in [Appendix A](#), Kolb defines those with a converging learning style to prefer learning using simulations and finding practical applications and solutions to problems. The pedagogical implications (PI) components of the web modules present practical strategies and considerations on how to translate the content knowledge for teacher application in the classroom. Thus, the PI component appears to be more distinctly aligned with the converging learning style than others, and as stated in the earlier literature

review, pedagogical content knowledge (both knowledge of content and how to teach it) comprise a major thrust for PD in science education for elementary teachers (Abell, 2007; Akerson & Hanuscin, 2007; Akerson, et al., 2009; Bransford, et al., 2000; Chen, Yang, & Li, 2008; Driver, et al., 1994; Driver, et al., 2000a; Harlen, 1997; Harlen & Doubler, 2004; Hennessey, 1999; Howes, 2002; Magnusson, et al., 1999). Thus this learner-content interaction type as a dependent variable is squarely supported by the literature for examination. To place this study in context, a summary of this literature will explicate the importance for this study.

Summary of Literature

For the past several decades, both national standardized student test scores in the United States for science in grades 4, 8, and 12 have been either stagnant or negative (U.S. Department of Education, 2006b), with similar lackluster results at the internal level as well (Bybee, 2008; Organization for Economic Co-operation and Development, 2007; U.S. Department of Education, et al., 2008). Many researchers agree that this performance in part is linked to teacher quality as defined by their knowledge and ability to apply subject matter knowledge and pedagogical content knowledge in the subjects they teach (Bransford, et al., 2000; Council of Chief State School Officers, 2007a; Darling-Hammond, 2006; Mestre & Cocking, 2002; Mundry, 2005; Weinburgh, et al., 2008; Whitehurst, 2002; Wilson, et al., 2002). The link between teachers' knowledge of science content and pedagogical content knowledge as subject matter for effective professional development in K–8 science education is strongly supported in literature regarding conceptual change, science education, and how students learn (Appleton, 2007; Bransford, et al., 2000; Driver, et al., 1994; Driver, et al., 2000a, 2000b; Feiman-Nemser, 2001; Heywood, 2007; Monk, 1994; Posner, et al., 1982; RMC Research Corporation & Center

on Instruction, 2008). Thus many reform movements and policy efforts are focusing on teacher improvement through professional development, with an emphasis in part on the importance of teacher content knowledge ("America Competes Act ", 2007; National Academy of Sciences, et al., 2007; National Staff Development Council, 2008; No Child Left Behind Act ", 2001; Sherwood & Hanson, 2008). Research also shows that at the elementary levels, if teachers are not competent and confident in their science content knowledge, they may shy away from the subject, spend little time on it in the classroom, and potentially facilitate misconceptions in their students (Abell, 2007; Abell & Smith, 1994; Appleton, 2007; Butts, et al., 1993; W. Carlsen, 1997; W. S. Carlsen, 1992; Garbett, 2003; Griffith, 2008; Grossman, et al., 1989; Harlen, 1997; Hashweh, 1996; Heywood, 2007; Howitt, 2007; Kang, 2007; C. A. Lee & Houseal, 2003; O. Lee, 1995; National Center for Research on Teacher Education, 1990; Parker, 2004; Schmidt & Buchman, 1983; Wilson, et al., 2002). National surveys confirm elementary and middle level teachers self-reported need to strengthen their own science content knowledge (Horizons Research, 2001, p. 37) and reveal the inadequate preparation they receive as part of their formal preparation in science (Council of Chief State School Officers, 2007a).

When reviewing the literature regarding professional development in general, researchers suggest 49 to 80 hours of continuous PD delivered over the course of a school year as necessary to facilitate a change in teacher practice (Banilower, et al., 2007; Garet, et al., 2001; Supovitz & Turner, 2000; K. S. Yoon, et al., 2008). Unfortunately, a recent federal schools staffing survey reported that 57% of teachers received less than 16 hours of PD during the prior school year (National Staff Development Council, 2008). Given there are approximately 1.7 million teachers of science at the elementary and middle school level in the United States (U.S. Department of Education, 2006a; U.S. Department of Education & National Center for Education Statistics,

2009), the question becomes what PD models are viable to address the scale necessary at a national level? How might we improve teachers' content knowledge through electronic professional development to reach all of our nation's teachers? Researchers clearly state the imperative to examine the effectiveness and efficiency of online models (Dede, 2006; Dede, et al., 2009).

Several studies in the literature are now exploring different levels of support in self-directed online professional development, examining areas such as the type, degree, and frequency of interactions across learner-learner, learner-instructor, and learner-content (Farahani, 2003; Krall, et al., 2009; Lapointe & Reisetter, 2008; Rhode, 2009; Schaller, et al., 2007). One of the underpinning theories guiding this research is the Equivalency of Interaction Theorem (T. Anderson, 2003). In this theory, Anderson argues that because of the increasing potential in computational, networking, and technological improvements, there is both the opportunity and the pressure to explore enhanced forms of learner-content interaction strategies given learner-instructor interactions are the most difficult to scale and learner-learner interactions may not be always preferred for certain adults juggling full-time careers, family, and online study (del Valle & Duffy, 2009; Jiang, et al., 2006; Lapointe & Reisetter, 2008; Rhode, 2009; Su, et al., 2005).

Several experimental and quasi-experimental studies involving both mixed method, quantitative, and qualitative designs find support for this theory. For example, the Russell et al. (2009) study, found similar effective learning outcomes for 145 middle level teachers (grades 5–8) participating in self-paced online PD with no learner-learner interaction compared with teachers that received moderated online PD (e.g., facilitators and learner-learner interactions). Similar results were reported in a mixed method study looking at different interaction forms most desired by 10 adults in self-paced online courses that were part of a 1-year PD certificate

program (Rhode, 2009). Lapointe and Reisetter (2008) examined 74 graduate students' perceptions of online learning communities and found that students experienced significantly more interaction with their instructor versus their online peers and that there were differences in the preferred amount of support desired, with some preferring peer interaction, and others desiring self-regulated, independent learning with little learner-learner interaction. Several NSF-sponsored studies by Schaller, Allison-Bunnell, Borun, and Chambers (2002; 2007) looked at informal learning preferences between adults and children, exploring the effects of learning style, age, and gender on user preferences for on-demand, web-based learning, specifically learner-content interaction preferences. Using Kolb's Learning Style Inventory 3.1 (2005), they found that learners' preferred style for learning does influence their preference for certain types of online learning activities, particularly among adults. The Schaller et al. studies (2002; 2007) employed online surveys and web log analysis from over 5,600 users across more than 11 museum websites. Finally, an examination of the literature presented studies that looked at the various types of variables under examination for self-directed professional development (e.g., age, years teaching experience, learning style preference, learner-content interaction strategies) (del Valle & Duffy, 2009; Harlen, 2004; Hoskins & van Hooff, 2005; Jiang, et al., 2006; Krall, et al., 2009; Rhode, 2009; Schaller, et al., 2002; Schaller, et al., 2007). Collectively, these studies begin to lend some insight into the importance of analyzing differences in adult learning preferences for the purpose of designing scalable and sustainable learner-content centric electronic professional development.

Problem Statement

This study sought to determine the importance and learning impact of learner-content interaction via on-demand, self-directed electronic professional development for elementary science teachers. It examined the following interactive features embedded in a self-paced on-demand web learning module: (a) science content narrative, images, animations, audio, and glossary, collectively designated as interactive reference; (b) embedded hands-on opportunities grouped as hands-on; (c) pedagogical implications component that translates learning for classroom contexts by grade band designated as practical application; (d) embedded follow-up questions and end-of-unit formative quizzes that provide descriptive feedback and varied user engagement such as drag and drop, multiple-choice single and multiple answer, and hotspot question items, all collectively grouped as personal feedback; and (e) interactive simulations where users may control variables and parameters of the interactive and observe resultant outcomes, collectively known as simulations.

Teacher perception of learning impact and preference for the different learner-content interaction strategies enumerated above (e.g., simulation, hands-on, etc.) will be measured via an online survey and correlated against the following learner demographics: (a) age and (b) years teaching experience. Learning style preferences as measured via the valid and reliable Kolb Learning Style Inventory (LSI) 3.1 (2005) were analyzed to see which learner-content interaction type enumerated above is preferred by each category of learning style. The juxtaposed learner styles of (a) accommodating, (b) diverging, (c) assimilating, and (d) converging identified via the LSI 3.1 (A. Y. Kolb & Kolb, 2005) are based on the Experiential Learning Theory (D. A. Kolb, 1984). These learner style preference variables will be analyzed to uncover significant relationships when compared with learner demographics, as well as the different types of learner-content interactivity available in self-directed web modules, thus informing designers of which

on-demand e-PD features within content are worthwhile for development from both educator preference and learning efficacy. The following research question and hypotheses are addressed in this study.

Research Question and Hypotheses

There is one major question driving this research: Which features of on-demand, self-paced online professional development have the greatest import and learning value for elementary educators and how do they differ for online learners with varying characteristics, focusing specifically on learner-content interaction as described by Anderson's 2003 Equivalency of Interaction Theorem? Asynchronous on-demand e-professional development in the form of interactive web-based science content modules were analyzed using correlation analysis and analysis of variance to explore the relationships between the independent variables of age and years teaching experience for elementary level science educators (grades three – six) and five distinct types of learner-content interaction strategies available within web-based modules (Hypothesis 1 and Hypothesis 2 below). The five learner content-interaction strategies examined were: (a) interactive reference, (b) pedagogical implications, (c) hands-on activities, (d) personalized feedback, and (e) simulations. Correlational relationships between the dependent variable of teacher learning achievement and the independent variables of learner demographics (i.e., age, years teaching experience) were explored via pre- and postassessments for those teachers that have completed and passed various web-based modules (Hypothesis 3 and Hypothesis 4 below). Correlation analysis (or multiple regression if looking at predictor variables), is the preferred statistical approach given it accommodates the researcher's analysis of categorical, continuous, or combinations of the two types of independent variables (Pedhazur

& Schmelkin, 1991, p. 309). The independent variables of learning preference were analyzed via multiple one-way analysis of variance for congruence between the perceived effectiveness or interest in one of the five learner-content interaction strategies (categorical variables), which were measured via a Likert scale survey (continuous variable), and participants' preferred learning style as measured via the Kolb LSI 3.1 (2005) (i.e., accommodating, diverging, assimilating, and converging) for Hypothesis 5 below. Finally, at the request of the committee, Hypothesis 6 analyzed the preassessment, postassessment, and final assessment scores from the sample to see if significant learning occurred for those that passed and completed the self-directed web modules. Below are the six hypotheses for this study.

Hypothesis 1. Age will be positively correlated with the type of preferred interaction desired in on-demand, self-directed web modules (e.g., simulation, interactive reference, hands-on, pedagogical implications, etc.) (del Valle & Duffy, 2009; Farahani, 2003; Hoskins & van Hooff, 2005; Kayes, 2005; Schaller, et al., 2007).

Hypothesis 2. Years teaching experience will be positively correlated with the type of preferred interaction desired in on-demand, self-directed web modules (e.g., simulation, interactive reference, hands-on, pedagogical implications, etc.) (del Valle & Duffy, 2009; Kayes, 2005).

Hypothesis 3. Age will be positively correlated with achievement as measured via a pre- and postassessment and final assessment for teachers who have completed and passed the online self-directed web-based module (del Valle & Duffy, 2009; Hoskins & van Hooff, 2005; Kayes, 2005).

Hypothesis 4. Years teaching experience will be positively correlated with achievement as measured via a pre- and postassessment and final assessment for teachers who have

completed and passed the online self-directed web-based module (del Valle & Duffy, 2009; Kayes, 2005; Russell, et al., 2009).

Hypothesis 5. Adult learners will prefer an online interaction type that will match their individual learning style over one that does not when accessing online, self-directed learning that focuses on learner-content interaction as the primary vehicle for learning (Farahani, 2003; Harlen & Doubler, 2004; Krall, et al., 2009; Lapointe & Reisetter, 2008; Rhode, 2009; Schaller, et al., 2007; Su, et al., 2005). All participants will rank simulation and hands-on PD opportunities high given its emphasis in the science education profession (Bayraktar, 2001; Downing & Holtz, 2008; Harlen & Doubler, 2004; Krall, et al., 2009; National Research Council, 2000; Vogel, et al., 2006), and pedagogical implications will be least favored given it is the least interactive online content strategy of the five being examined.

1. Teachers identified with the Kolb (2005) assimilating learning style preference will rank interactive reference content most favorable (i.e., science content narrative, audio, images, animations, and glossary).
2. Teachers identified with the Kolb accommodating learning style preference will select hands-on activities most favorably.
3. Those teachers identified with the Kolb converging learning style preference will favor simulations and the pedagogical implications content-interaction strategy.
4. Those identified with Kolb diverging learning style preference will rank the personal feedback component (embedded follow-up questions and end-of-unit formative quizzes) as most favorable.

5. Other than those identified with the Kolb converging learning style preference, pedagogical implications will be identified as the least favorable interaction strategy given it has the least amount of engaging interactivity (e.g., just narrative text and images).

Hypothesis 6. Teachers completing the 10-hour web modules and passing the final assessment at its conclusion will demonstrate significant gains in learning.

The research questions and hypotheses from this study hope to address several areas of significance for both the research community, as well as practitioners in the field that design or administer professional development.

Significance of the Study

Findings from this research will inform instructional designers and curriculum developers who create online professional development as to which interactive components of online content may be most engaging for adult learners and which may maximize learning given various demographic data and learning preferences of teachers in grades three – six participating in this study. Additionally, this research will inform education administrators who are charged to make significant financial and programmatic decisions regarding the suite of professional development opportunities available for teachers within their schools, districts, and states. Finally, data from this research support a major thrust of current research in online professional development and will inform an emerging theory concerning the degree and nature of online content for learners focused on learner-content interaction as described by Equivalency of Interaction Theorem (T. Anderson, 2003). In addressing these areas of concern a detailed description of the methods and procedures follows.

Chapter 3: Methodology, Variables, and Instruments

The purpose of this quantitative study is to determine if there are relationships between upper elementary teachers' age, years teaching experience, and learning style preference as compared with their perceptions of which features of on-demand, self-directed online professional development are of the greatest import and learning value. Multiple statistical methods that include correlation analysis, multiple one-way analysis of variance, and paired sample *t*-tests were employed to uncover relationships between the independent variables of age, years teaching experience, and learning style preference and the following dependent variables: (a) preferred learner-content interaction strategy and (b) posttest content knowledge using a pretest of science content knowledge (covariate), for teachers (grades three – six) that have completed and passed an online self-directed web module in professional development. The organization of this chapter presents the methodology and design for this study to address the research questions under examination. The criteria for participation and a description of the teachers who volunteered to participate is provided, which is then followed by a review of the instruments used. The pilot study for one of the online instruments—a teacher perception survey that is combined with an existing instrument—is provided as well as the procedure applied to collect the data. This chapter ends with a rationale for the type of data analysis applied and closes with a chapter summary.

Study Design

In determining the best approach to answer this study's research questions, a non-experimental approach design was selected. Descriptive research as defined by Gall, Gall, and Borg (1999) “involves the collection and analysis of quantitative data in order to develop a precise description of a sample's behavior or personal characteristic” (p. 173). Similarly, Gall et

al. (Gall, et al., 1999) and others (McMillan, 2008) describe the purpose of correlation research as one that seeks to investigate the relationship between variables, with its value being that it permits researchers to determine the degree and direction of the relationship between the variables under analysis. These two definitions seem best suited to describe this research design. As this study does not apply random sampling procedures, random assignment to treatments, or the manipulation of variables in determining cause and effect, it does not seek to generalize the findings to a larger population but to explore the relationships between the variables in question (Pedhazur & Schmelkin, 1991). While consensus on the “labeling” of nonexperimental research varies (Pedhazur & Schmelkin, 1991), this correlational study combines multiple instruments and a cross-sectional online survey to discern the relationships between the following variables of interest as drawn from the literature: (a) teacher demographic variables (e.g., age, years teaching experience), (b) teachers’ preferred learning style, (c) teachers’ preferences for five different learner-content interaction strategies, and (d) teachers’ perception of the learning effectiveness for each of the five learner-content interaction strategies. This study also draws from existing archived teacher assessment data to compare teachers’ pre- and postassessment scores as aligned with their completion of self-directed online science content modules. This data is also correlated against the independent variables of age and years teaching experience, as well as the learning effectiveness observed after teachers completed and passed online self-directed science content modules. It should be noted that Pedhazur and Schmelkin (1991) and Gall et al. (1999) caution researchers in (a) generalizing the interpretations found in nonexperimental designs (b) using the terms *independent* and *dependent variables*, and (c) interpreting regression coefficients as “indices of the effects of variables with which they are associated on the dependent variable” (p. 374). Given the cautions associated with nonexperimental designs and

their limited external validity, for this descriptive study, correlational relationships between variables are explored and predictive regression analysis is avoided, as they are subject to severe biases in regressions estimations when nonprobabilistic sampling is employed (Pedhazur & Schmelkin, 1991). A discussion of the selection process and criteria for participants follows.

Research Participants and Criteria for Participation

The population under examination is upper elementary teachers in grades three – six. Given the study’s focus to identify learning preferences as correlated with different learner-content interaction strategies, the population was restricted to teachers who completed a 10-hour self-directed web module in one or more science content areas, which incorporated the different content interaction-strategies under examination. Additionally, the population and resultant sample was limited to teachers who had completed a pre- and postassessment and passed a separate final assessment aligned to its respective science content web module. Thus, a nonprobabilistic judgment sampling technique was employed, which as described by Marshall (1996) is based on an “intellectual strategy” where the researcher develops a “framework of the variables that might influence an individual’s contribution” incorporating theory, availability, literature in the area, and the researcher’s practical knowledge (p. 523).

At the time the sampling frame was determined, the size of the eligible pool fulfilling the requirements above was 708 K–12 science teachers from a database of teachers at the National Science Teachers Association (NSTA). An exact sampling frame of educators in grades three – six from this population was unknowable, given privacy issues and limited demographic information required to create an educator account to access the web-based science content modules. Eighty-five educators from grades three – six volunteered to participate in the study,

residing in 11 states: (a) Connecticut, (b) Georgia, (c) Illinois, (d) Kentucky, (e) Montana, (f) Ohio, (g) Oregon, (h) Pennsylvania, (i) Texas, (j) Washington, and (k) West Virginia. Given the selection requirements enumerated above for study participation, [Table 2](#) provides a distribution of the 708 eligible across the seven different science content areas examined.

Table 2
Completion Frequencies of Pre- and Postassessments for Selected Web Modules

Web Module Science Content Area	Number that have completed the online pretest and posttest, and have passed the final assessment at the conclusion of the web module
Force and Motion	296
Energy	173
Ocean’s Effect on Weather and Climate	86
Solar System	25
Earth’s Changing Surface	35
Cell Structure and Function	47
Nature of Light	46
Totals	708

The final within-subject survey included 85 educators generating 102 unique response sets of data where 15 of the 85 educators completed a second learner-content interaction preference survey, and 2 of the 85 educators completed a third survey given had completed 3 self-directed science content web modules. In each case these 17 “repeat contributors” fulfilled the selection requirements for eligibility (i.e., teaching in grades three – six, completed the pre- and postassessment, and passed the final assessment at the end of the web module). An expanded description of the sample demographics appear in the results section of Chapter 4. With the

participant sample adequately described, this section will close with a summary and justification of the sampling selection size and method for the study at hand.

This sample is of sufficient size to ensure the necessary rigor for the statistical analysis applied and large enough to detect differences observed within the sample itself (Pedhazur & Schmelkin, 1991). If this study have employed a random sample technique, Dillman, Smyth, & Christian (2008) provide explicit examples and equations to determine the necessary sample size for a desired confidence level and sampling error, given the size of population. For example, given a 90% confidence level with a population of 708 participants, and a .05% sampling error, one would need to draw a random sample of 85 participants to garner similar results in 18 out of 20 samples where “the true population value for the question” would be within 5 percentage points of the sample estimate (p. 208). Other psychometricians focus the discussion on sample size as a function of the desired power of the study or the effect size of the treatment (Cohen, 1988, 1992; Pedhazur & Schmelkin, 1991). Given a large enough sample, studies may achieve statistically significant findings from a purely mathematical perspective, but garner little practical research significance if the power of the study is not taken into consideration (Cohen, 1988; Gall, et al., 1999; McMillan, 2008). If one determines the desired power and significance criterion (α coefficient) before the study, and a known effect size for the treatment and instruments are established, then the size of the required sample may be easily determined, such that if mathematical significance is found, the study will also have relevancy in its application. An application of Cohen’s equations (1988, 1992) would require the following sample sizes given the generally accepted power level of .80, with a medium effect size: (a) 85 participants using the Pearson Product Moment correlation (H1–H4 for this study), (b) 45 participants using a 4 group trial ANOVA, and (c) 64 participants using paired sample *t*-tests (H6 for this study).

Similarly, one may also critique a study's power (or practical worth) post hoc if the effect size is meaningful and the power high (Cohen, 1988, 1992; Pedhazur & Schmelkin, 1991). If the test of power is low, this does not necessarily mean there is no effect between the variables under study, but that the design of the study might be repeated under more favorable conditions (e.g., a larger sample size). Ironically, for the social sciences, given the complex interaction between the myriad variables at play, most studies rarely find large effect sizes (Feldt, 1973; Pedhazur & Schmelkin, 1991). While this discussion demonstrates an adequate sample size was obtained from multiple probabilistic sampling perspectives, the descriptive exploratory nature of this study is not intended to generalize its findings beyond the sample data. Similarly, given it employed partially new instruments without an a priori model or published effect size estimates, and involved a nonprobabilistic sample, the use of power analysis to determine sample size is not appropriate (Cohen, 1988; Pedhazur & Schmelkin, 1991). Alternatively, for nonprobabilistic samples Sue and Ritter (2007) suggest the following guidelines: (a) sample sizes should be no smaller than 30 and larger than 500, (b) a sample should be within about 10% of the size of the parent population within the 30 and 500 participant limits, (c) multivariate research should contain samples at least 10 times larger than the number of variables being studied, and (d) larger samples are generally better than smaller ones. Given there are a total of eight variables under examination for this study from an eligible population of 708 or less potential teachers from grades three – six, a sample size of 85 respondents meets these general guidelines.

The design of this study used a volunteer purposive or judgment sample (Marshall, 1996; Nesbary, 2000) from a selected target population that completed self-directed e-PD modules across a range of grades and science content areas seeking to uncover relationships between the variables in question as posited by the literature and Anderson's Equivalency of Interaction

Theorem (T. Anderson, 2003). As Pedhazur and Schmelkin (1991) caution, in nonexperimental designs, groups may be compared and formulated based on the assumption of exposure to the dependent variable, when in fact this may not be the case, thus making statements about the effects untenable. Fortunately, this caution does not apply here, as only participants who completed the web module final assessment and pre- and postassessment scores were invited for participation in this study. This preselection criteria assured only teachers who had been exposed to the treatment and preassessment measures were invited. Additionally within the survey instrument explicit refresher examples from the completed web modules provided screen captures (see [Appendix E](#)) to reacquaint the participants' memory to the different content-interaction strategies under examination. For a variety of reasons (e.g., remuneration, interest in the topic, curiosity, etc.), the correlational relationships and preferences determined from this sample should not be advanced to the larger population. With a description of the participants and their selection criteria justification of the sampling design explicated, a review of the instruments used in the study follows.

Instrumentation

A learning preference style inventory, a pre- and postassessment instrument across specific science content areas, and a learner demographic and learning preference survey constitute the three instruments that undergird this study. First, the Kolb Learning Style Inventory (LSI) Version 3.1 (2005) is a 12-item survey generating 48 learner responses to determine an individual's preferred style for learning among four discrete categories and the interval subscales of concrete experiences (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). See [Figure 2](#) and [Figure 3](#) for

illustrations depicting the underlying theory and learning preference descriptions respectively. Appendix A provides a description of the different learning styles and underlying Kolb Experiential Learning Theory (D. A. Kolb, 1984). The Kolb LSI 3.1 has peer-reviewed studies reporting internal consistency reliabilities for the four learning style constructs (CE, RO, AC, AE) between .70 and .84 (Kayes, 2005; Ruble & Stout, 1991; Veres, Sims, & Locklear, 1991; Wiestra & DeJong, 2002) and test-retest reliabilities for the same for four learning styles subscales above .9 (Veres, et al., 1991). Permission was secured on September 15, 2009, to use the Kolb LSI 3.1 instrument (see Appendix F).

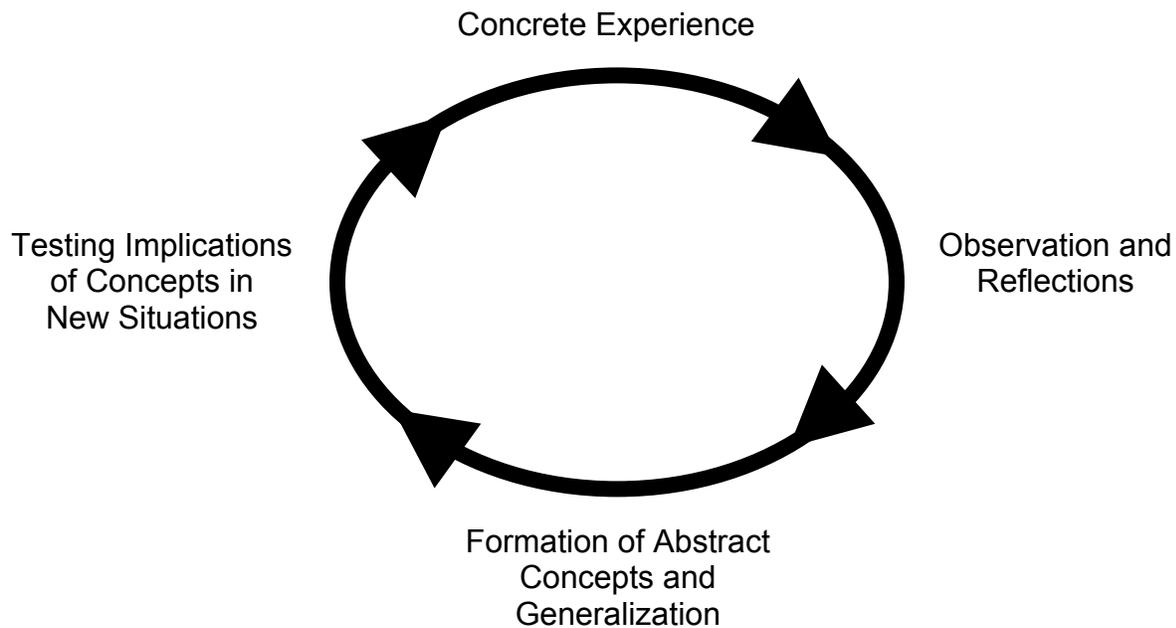


Figure 2. The Experiential Learning Cycle. Used with written email permission of Alice Kolb, 2010. Kolb, A.Y., and Kolb, D.A. (2005). The Kolb Learning Style Inventory—Version 3.1. 2005 Technical Specification. The Hay Group. Available from http://www.learningfromexperience.com/images/uploads/Tech_spec_LSI.pdf, 2010.

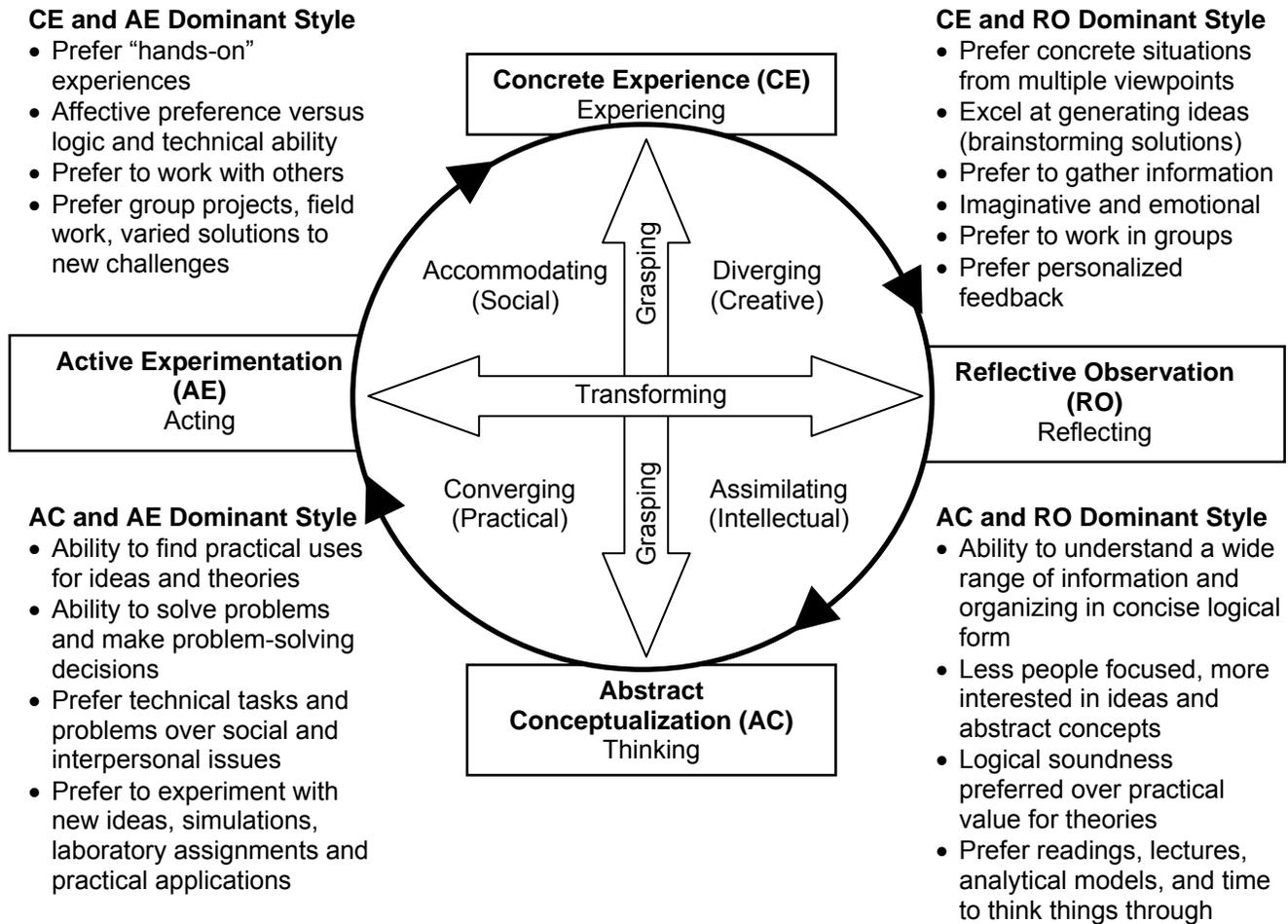


Figure 3. The Kolb Learning Style Preference Scales—Version 3.1. Used with written email permission of Alice Kolb, 2010. Kolb, A.Y., and Kolb, D.A. (2005). The Kolb Learning Style Inventory—Version 3.1, 2005 Technical Specification. The Hay Group. The Kolb Learning Style Inventory: PowerPoint slides, The Hay Group (2006). Available from:

http://www.haygroup.com/tl/Questionnaires_Workbooks/Kolb_Learning_Style_Inventory.aspx, 2010.

The pre- and postassessment instrument documented the direction and magnitude in content knowledge after teachers completed the online 10-hour web-based module. This instrument was developed by the National Science Teachers Association and incorporates a content validity review process and pilot testing of items that have garnered Chronbach α internal reliability coefficients ranging from .609 to .882 for each science content pre- and postassessment with the majority of items ranging in acceptable levels of .704 and above. See [Appendix G](#) for an overview of the item development process for instrument and sample content validity and reliability statistics for various pre- and postassessments for science content.

The learner-content interaction strategy preference survey was developed using a subset of content-interaction types from various web modules that a majority of learners experienced. Examples of these content-interaction strategies are depicted in [Appendix C](#). The online teacher perception survey was developed and delivered via SurveyMonkey software and consisted of the following components: (a) title; (b) written introduction explaining the purpose of the survey; (c) demographic questions; (d) first learner content-interaction strategy name; (e) brief description of the content-interaction type; (f) one example of the content-interaction type that all or most participants have completed; and (g) attitude items, before the cycle is repeated for each of the remaining four learner-content interaction types. The attitude items evaluated the following: (a) individuals' preference for each component, (b) individuals' perceived learning effectiveness for each component, and (c) individuals' perceived learning retention effectiveness for each component. An example of the format and type of online survey questions that were repeated for each content-interaction type appears in [Appendix E](#). A pilot study ensured the instrument was accessible and clear in its directions and nature of the teacher perception questions asked. The individual measures of reliability for the five-item user preferences (i.e., engagement, facilitates

learning content, retention of content, facilitates teaching science, and desire for more of this type) were high across all seven science content preference surveys with Chronbach α reliability ratings of at least .91 or greater: (a) simulations Chronbach $\alpha = .91$, (b) hands-on Chronbach $\alpha = .96$, (c) personal feedback Chronbach $\alpha = .93$, (d) interactive reference Chronbach $\alpha = .94$, and (e) pedagogical implications Chronbach $\alpha = .96$. Chronbach α is a simple assessment of how well the items in the scale measure the same construct and support the appropriateness (reliability) of the instrument as a scale of measurement (Howell, 1997). The Chronbach α results above indicate that the five items for each content-interaction strategy form a statistically appropriate scale with which to test the hypotheses and reliably combine to create an overall satisfaction preference index for correlation against the variables under examination in this study (Howell, 1997). The teacher perception survey combined with the Kolb LSI 3.1 instrument, in its entirety, as one of four survey subsections and was pilot tested prior to deployment as suggested by literature (Babbie, 1990; Dillman, et al., 2008; Sue & Ritter, 2007).

Pilot Study

The four-part teacher perception survey was pilot tested with 8 educators in grades three – six. The pilot test focused on the following areas: (a) ease of access and completion that involved entering a unique user code and password, (b) clarity of directions and supporting examples for each learner-content interaction strategy, (c) length of survey, download times, and completion time, (d) useful feedback from open-ended questions, (e) completion of all question, and (f) ability to receive a free NSTA e-resource with a promotion code and redirect URL to NSTA's online bookstore (i.e., automated incentive). While pretesting added extra time during the initial phases of the study, it was strongly recommended in the research to ensure the best

chance of avoiding useless, confusing, or lost feedback data once fully deployed (Babbie, 1990; Sue & Ritter, 2007). Feedback garnered from all participants supported the clarity of the survey purpose, directions in its execution, and the ability to receive an automatic promotional code after completing the survey along with a redirect URL allowing educators to select and secure any e-Book from NSTA (up to a \$40 value depending on the book selected) and being entered to win one of 15 iPod Touches. Comments from the pilot testing group provided suggestions to simplify the directions at the conclusion of the survey regarding the process to receive a free resource from NSTA. The pilot study also permitted the testing of data collection and export via SurveyMonkey, and the accurate capture of the data for the Kolb LSI 3.1 embedded instrument, which required the creation of a rank-order question format to mimic the paper version of the same. Three additional pilot testers completed the survey after these revisions were implemented along with numerous “test runs” by the researcher across all seven different versions of this survey to match the seven different science content areas that were being examined. All seven surveys were identical in format, question type, and length with the only difference being the unique examples for each different science subject matter content area: (a) Force and Motion, (b) Solar System, (c) Cell Structure and Function (d) Earth’s Changing Surface, (e) Nature of Light, (f) Energy, and (g) Ocean’s Effect on Weather and Climate. The first wave of survey invitations ultimately was considered a pilot for this researcher. Of the 300 invited to participate in the first wave of emails, only 3 responded in the affirmative. Review of the process necessitated the following refinements: (a) more inviting language and the use of bold and color, (b) an improvement by adding graphics of the incentives within the email invitation itself, (c) an adjustment in the incentives offered including participants’ probability of winning the raffle component, and (d) a correction in the completion date required for the survey. The probability

of winning one of the 15 iPod Touches was adjusted and promoted as a function of the target sample size and 100 unique survey responses, not as a probability of 1 of 700 from the entire population being invited. The incentive reward for all respondents who completed the survey also changed from access to a web e-PD module to an NSTA e-Book of their choice. It seems that giving away an additional web module was little incentive given those being invited already had access to all available web modules as part of their district professional development experience. The method of data collection follows.

Data Collection Procedure

Data collection began with a back-end analysis from a database at the National Science Teachers Association of participants who met the requirements for this study, which is elementary teachers (grades three – six) who have completed and passed the final assessment for a single web-based NSTA e-PD module and have completed the related pre- and postassessment for the same web module. This generated a population and master Excel list of 708 K–12 educators. This list was then segmented by the seven different science content areas aligned with the seven self-directed web modules. A personalized email invitation was sent to the Force and Motion science content group on a Saturday and Sunday beginning on March 27, 2010. Wave one was already addressed above and considered part of the initial pilot given the significant adjustments and corrections made to successive invitations. A master Excel sheet tracked each successive wave of personalized invitations that went out on successive weekends to educators who completed web modules across the seven different content areas. In total, six waves of invitations were emailed over the period of 2 months with the last wave being sent out on May 23, 2010. On average approximately 100–200 educators were invited to participate in the study

each weekend. With the improved messaging, look, and incentives, self-selection response rates averaged 3–5% for each wave. In addition to the initial wave, repeat invitations were sent out to those who failed to respond to an earlier wave if 2 weeks had passed since they were initially invited. This was to avoid potentially irritating the potential respondent. No more than three repeat invitations went to any one individual. Following the recommendations from the literature, the invitations incorporated the following attributes to increase the likelihood of responding: (a) guaranteed incentive for all and opportunity for a raffled incentive with published probability of winning, (b) informing educators they were selectively chosen because of their unique status for participation in this research, (c) personalized invitation with participants' first name, (d) invitation from a personal email of someone with a senior title (e) re-inviting educators with follow-up invitations that include updated information concerning the progress of the study, (f) sharing importance of study and promising to share survey findings when the survey was completed, and (g) keeping the initial invitation engaging and compelling (Dillman, et al., 2008; Kaplowitz, Hadlock, & Levine, 2004; Porter & Whitcomb, 2003; Sills & Song, 2002; Sue & Ritter, 2007). This said, the researcher was unable to combine postcard follow-up reminders in a blended approach as suggested by some (Dillman, et al., 2008; Kaplowitz, et al., 2004) as this information was unavailable from the master database. Email contact was the only method to communicate and invite educators to complete the online teacher perception survey and agree to allow access to their pre- and postassessment scores.

The process to access the survey was somewhat cumbersome and required two separate email exchanges to grant the educator access to the online survey with secure socket layer encryption. The researcher could not provide a direct link to the web-based survey embedded in the initial email invitation for the following reasons: (a) SurveyMonkey's use policy strictly

forbids making a web survey URL available to anyone until after they agreed to receive the survey, and (b) in order to protect the confidentiality and anonymity of those participating, once they confirmed participation via a return email to the researcher, a follow-up email sent a unique three-digit user code, the password to access the survey online, and the informed consent as submitted and approved by Virginia Tech's Institutional review board. See [Appendix H](#) for a copy of the email invitations and informed consent and [Appendix I](#) for a copy of the IRB approval from Virginia Tech. When 102 unique responses were obtained from 85 unique participants, the researcher stopped inviting educators to participate from the K–12 master list. The overall response rate is difficult to determine as the researcher could not know how many of the 708 K–12 educators were from grades three – six. Once a teacher agreed to participate (responded to the email invitation), a completion rate could be determined as well as an estimate of the integrity of the population list from the number of valid versus invalid email addresses.

Only 2 educators of the 85 that agreed to participate did not complete the survey after they agreed to participate in the study. This signifies a completion rate of 97.5% across all eligible and self-selected participants. The master population list was fairly current as only 39 emails from the 708 were no longer active accounts that generated an “undeliverable” return email to the researcher. Assuming the nonreturned emails were still accessible to the population in question, this signifies access to 94.5% of the population of eligible candidates. It should be noted that sampling errors typical for online survey research such as self-selection bias, non-response bias, and noncoverage errors (Sills & Song, 2002; Wright, 2005) are not germane here given the researcher is not attempting to generalize the findings to the larger population beyond the sample investigated in this exploratory descriptive study. The focus is the quality of the content and the relationships revealed between the variables under examination. This

acknowledged, all three of these typical challenges in sampling errors arise from the fact that the sample drawn may not equitably represent the population to which one wants to infer findings. For example, internet surveys may cater to those with more access or who are more technology savvy, or in the case of noncoverage error, this occurs when the sampling frame fails to include all members of the population under question (Sills & Song, 2002; Wright, 2005). In both of these concerns the sampling frame for this study avoided those issues by purposely including only those with online access that had already completed the self-directed web module. As stated earlier, bias due to nonresponses is not applicable for this study, but even with probabilistic survey samples, web survey response rates vary greatly from 14% to 70% (Sills & Song, 2002) and are typical of those encountered with print mail surveys (Kaplowitz, et al., 2004). Once the data was aggregated in SurveyMonkey, it was downloaded into a master Excel file and imported into SPSS predictive and analytic software, which ran the Pearson Product Moment correlations, the one-way analysis of variance using split file features to parse only that data as grouped by a particular learner preference variable, and paired sample *t*-tests.

Data Analysis

Below is a listing of the types of analysis that were applied for each set of variables and hypotheses. Descriptive statistics describes the participants' demographic and career variables and their preferences of and learning impact perceptions of the five different learner-content interaction strategies (e.g., hands-on, simulations, interactive reference, etc.). Descriptive statistics help in organizing, presenting, summarizing, and understanding the characteristics of the sample selected for study (Gall, et al., 1999; McMillan, 2008). For Hypotheses 1–4 (H1–H4) bivariate Pearson Product Moment correlations sought to uncover any relationships between age,

years teaching experience, learner achievement, and preference for and perceived learning impact of the five learner-content interaction strategies. The Pearson Product Moment correlation (r) is the appropriate statistic for determining the degree of relationship when comparing only two variables as it is simply the covariance between the scores after they have been standardized as z scores (Babbie, 1990; Gall, et al., 1999; Pedhazur & Schmelkin, 1991). With a small standard of error, Gall et al. (1999) state that researchers often use the Pearson Product Moment for any two sets of scores, even if they are not continuous, but for H1–H4 in this study, the data are continuous (both interval scale and ratio scale data). The use of the Pearson Product Moment correlation and not simultaneous multiple regression was a refinement from the statistical procedure proposed at prospectus, but in consultation with my advisor, it was recommended as the more appropriate analysis method given the sampling technique required to secure participants for this study.

Hypothesis 5 (H5) data were analyzed using a general linear model repeated measures one-way analysis of variance (ANOVA) to compare teachers' learning style preference (independent variable) as related to content-interaction strategy preferences captured via an online survey. ANOVA is the appropriate test of statistical significance when more than two means need to be compared simultaneously (Gall, et al., 1999; Pedhazur & Schmelkin, 1991), and repeated measures applies as participants were measured on the dependent variable multiple times as exposed to different conditions. In this study a within-subjects factor ran a "split-file" using SPSS to separately report out individuals' Kolb learning style preference (2005), and then repeated measures ANOVA were run on the learner-content interaction strategy indexes to look for differences. One could perform multiple t -tests comparing mean score differences between all the possible relationships, but this procedure is not only tedious, it mathematically increases

the likelihood of creating a Type I error (i.e., falsely rejecting the null hypothesis) (Pedhazur & Schmelkin, 1991). As Gall, et al. (1999) state, “analysis of variance is a more elegant and accurate method of making all the comparisons at once to determine which ones are likely to be chance differences” (p. 162). The independent learning style preference variable is continuous interval data that places teachers in one of four learning preference categories (i.e., diverging, assimilating, converging, or accommodating). Teachers’ learning styles were then compared with their perceived preferences of and learning potential for five different content interaction strategies as defined by the literature regarding self-directed learning in science education. The within-subjects ANOVA statistic makes the assumption that the population from which the sample was drawn is symmetrical or “spherical,” (i.e., the variances are all equal to zero) (Lane, Lu, Peres, & Zitek, 2008; Mauchly, 1940). This “assumption of sphericity” is a restrictive assumption that if violated, can lead to a substantial increase in a Type I error rate, and in fact the assumption of sphericity is rarely obtained in practice (Lane, et al., 2008). The Geisser Greenhouse correction was applied in SPSS, which adjust the degrees of freedom downward to correct for this violation, ultimately adjusting the *F* score downward and decreasing the chance to reject the null hypothesis (Lane, et al., 2008). When statistical significance was found, a priori comparisons were executed (e.g., those planned before the data was collected based on study hypotheses and literature) (Ross & Morris, 2004; Sheskin, 2004). In essence, there is no difference between the a priori multiple *t*-tests procedure and using Fisher’s least significant difference (LSD) post hoc comparison, other than that the LSD method requires a significant *F* value for the overall analysis of variance (Howell, 1997). This was achieved in this study for all one-way repeated measures ANOVA, and as such, Howell (1997) states “a significant overall *F* ensures that the familywise error rate will equal α ” (p. 269).

For Hypothesis 5 (H5) the teacher online survey used in H1 captured Likert scale data regarding teachers' preferences for the different learner-content interaction types listed below. The Kolb Learning Style Inventory 3.1 (2005) determined individuals' preferred learning preference (interval data, independent variable) and was collected as an embedded part of the online preference survey. Using the split file feature in SPSS, the data was parsed by the learner preference group variable for examination using a one-way analysis of variance. This analysis process tested for the difference(s) between the five specific learner-content interaction strategies that are suggested as an effective fit from the literature (A. Y. Kolb & Kolb, 2005). In essence learners were recoded into one of four categories (i.e., diverging, assimilating, converging, and accommodating) and then analyzed against their preference for, and/or perceived effectiveness of, specific interaction strategies (i.e., simulations, interactive reference, personal feedback, hands-on, pedagogical implications). Both individual and a pooled overall content preference index from the learner content preference survey were calculated by averaging responses to the five-item survey. The measure of scale cohesiveness or internal consistency (e.g., how well the five learner-content preference items correlate with each other in measuring the same construct, or their level of homogeneity) was also determined (i.e., Cronbach α) (Pedhazur & Schmelkin, 1991). Executing multiple one-way ANOVAs for each learner preference variable allowed a determination of which learner-content interaction strategy might be more favorable over the other four learning preference subcategories (i.e., diverging, assimilating, converging, and accommodating). See [Table 3](#) for a representation of the multiple ANOVA analyses. This analysis of variance included a priori planned comparisons (executed via custom coding in SPSS). In order to guard against Type I error, a Least Significant Difference (LSD) adjustment was made to adjust for the multiple comparisons. A priori comparison is one that is designed to

be run before the data is collected in which multiple *t*-tests comparisons are permitted (Howell, 1997). In essence the a priori comparison is similar to Fisher's post hoc LSD, but requires a significant *F* for the ANOVA before proceeding (Howell, 1997). In this study the total number of planned variables for H5 being compared is five (i.e., five different types of content-interaction strategies). The total number of comparisons is large, thus the necessity to adjust for multiple comparisons via the LSD adjustment. The total list of all 5 possible learner content-interaction comparisons include the following: (a) hands-on versus simulation, (b) hands-on versus interactive reference, (c) hands-on versus pedagogical implications, (d) hands-on versus personal feedback, (e) simulation versus interactive reference, (f) simulation versus pedagogical implications, (g) simulation versus personal feedback, (h) interactive reference versus pedagogical implications, (i) interactive reference versus personal feedback, and (j) pedagogical implications versus personal feedback (i.e., 1 vs. 2, 1 vs. 3, 1 vs. 4, 1 vs. 5, 2 vs. 3, 2 vs. 4, 2 vs. 5, 3 vs. 4, 3 vs. 5 and 4 vs. 5).

Finally, for Hypothesis 6 (H6), teacher learning gains were analyzed between the pretest and posttest and pretest and final assessment means scores using paired sample *t*-tests after teachers completed and passed the online self-directed web module final assessment. Gall et al. (1999) and Pedhazur and Schmelkin (1991) recommend the paired sample *t*-test as the appropriate method to determine if the difference between the mean scores of two groups is significantly different statistically as long as the following assumptions exist: (a) only matched pairs are used

Table 3
Hypothesis 5: Learner Style Preference Will Match Interaction-Content Preference

Independent Variables	Learner-Content Interaction Strategy Types (Dependent Variables)				
	Interactive Simulations	Hands-On Activities	Pedagogical Implications	Personal Feedback	Interactive Reference
Diverging Learning Preference Teachers (ANOVA 1)	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content
Assimilating Learning Preference Learners (ANOVA 2)	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content
Converging Learning Preference Learners (ANOVA 3)	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content
Accommodating Learning Preference Learners (ANOVA 4)	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content	1. Engagement Level 2. Facilitates learning 3. Facilitates retention 4. Facilitates teaching 5. See more content

NOTE: Results from H1 and H2 will show degree of correlation between different content interaction strategy types above and age and years teaching experience.

The five learner content preference type questions (e.g., engagement, facilitates learning, retention, etc.) were pooled as single “satisfaction” construct.

for analysis, (b) scores are normally distributed, (c) variance between the paired samples are the same, and (d) observations are independent of each other. While these assumptions were maintained for this study, given there was no control group to compare pre- and postassessment scores, or random assignment employed to equally distribute extraneous participant variables, attributing teacher learning to the treatment (i.e., the web modules) is tentative if statistical significance is found. Thus, threats to internal validity may exist if generalizations to the population are made (Gall, et al., 1999; Pedhazur & Schmelkin, 1991). The committee did request this additional H6 analysis and with cautions duly noted, it will be of interest to report as important contextual data germane to this overall study.

Delimitations and Limitations

Delimitations are those limitations self-imposed by the researcher based on the design selected for the research study (Rudestam & Newton, 2007). Given this study is descriptive and exploratory in nature, the main delimitation is the limited external validity of the sample findings to the population from which it was drawn. Pedhazur and Schmelkin (1991) and others (Gall, et al., 1999; McMillan, 2008) caution researchers in making any statements of causation. While this study did uncover relationships between learning achievement, age, years teaching experience, learning style preference and learner-content interaction strategies as supported by the literature, inferring for example, that educators learned significantly more because they completed and passed the self-directed web modules is highly tentative with no quasi-experimental design or control group (Pedhazur & Schmelkin, 1991). Similarly, internal threats to validity such as testing (e.g., pretest sensitization) and selection (e.g., volunteer self-selection) (Ross & Morris, 2004), as well as survey response bias due to nonresponses or coverage errors (Sills & Song,

2002; Wright, 2005), are all issues that have the potential to bias findings and are delimitations in this study. Conversely to delimitations, general limitations deal with areas that the researcher has no control over (Rudestam & Newton, 2007). Given the variables of interest in this study related to self-directed electronic professional development for teachers in grades three – six, the researcher was restricted to a narrow population of those who met the parameters for participation. The database allowed filtering to select only educators who had completed and passed a self-directed web module and taken both a pre- and postassessment but did not permit filtering within K–12 grade levels. The only contact information to invite participants for participation from the K–12 list was by email. The researcher also dealt with an unknown sampling frame size and the inability to conduct a random sample or blended invitation survey method (using both mail postcards and email) to increase survey response rates (Dillman, et al., 2008; Kaplowitz, et al., 2004) as the database of eligible participants only contained email addresses (e.g., no mailing address information or grade levels taught). With these delimitations and limitations noted, a summary of the methodology concludes this chapter.

Summary

The design of the descriptive exploratory quantitative study is to determine if there are relationships between upper elementary teachers' age, years teaching experience, and learning style preference as compared with these teachers' perceptions of which features of on-demand, self-directed online professional development are of the greatest import and learning value. The theoretical models of Anderson's Equivalency of Interaction Theorem (2003) and Experiential Learning Cycle by Kolb (1984), coupled with the research focused on learner-content interaction (Rhode, 2009; Russell, et al., 2009; Schaller, et al., 2002; Schaller, et al., 2007) support this data

analysis. Correlation analysis, multiple one-way analysis of variance with a priori *t*-test comparisons, and paired sample *t*-tests revealed relationships between these independent variables, and a pretest of science content knowledge (covariate), with the following dependent variables: (a) preferred learner-content interaction type and (b) posttest content knowledge. The criteria for participation were teachers in grades 3–6 that completed and passed an online self-directed web module in professional development. A total of 85 teachers from 11 states generated 102 unique survey responses. Three separate instruments were part of this study: (a) the Kolb LSI 3.1 (2005) learning preference inventory, (b) a pre- and postassessment instrument across seven different science content areas, and (c) a learner demographic and learning preference survey. A pilot study validated the online learner preference survey, which included the Kolb LSI survey as a component of the larger survey. The breakdown of the analysis is as follows. The first two hypotheses (i.e., H1 and H2 respectively) predicted that there would be a relationship between age, years teaching experience (both continuous ratio data) and the preferred type of content-interaction preferences and perceptions of learning (interval scale data) as classified via the Learning Preference Survey ([Appendix E](#)), and as aligned with the different components available in the online self-directed web modules. Similarly, Hypotheses 3 and 4 predicted that there would be a correlation between age and years teaching experience as related to learning achievement via the postassessment data (continuous ratio data) as measured by the NSTA Pre- and Postassessment Instrument ([Appendix G](#)) and the learner demographic preference survey and preassessment data (continuous ratio data). Pearson Product Moment correlations were used for H1–H4. Hypothesis 5 predicted that learners would prefer an online interaction type that matches their individual learning style for online self-directed PD modules. A repeated measures ANOVA comparing teacher perception of learning impact (i.e., learning

effectiveness, learning retention) for five different interaction strategies (e.g., simulation, hands-on activity, etc.) was captured using the learning preference survey and compared against teacher learning style preference via the Kolb LSE 3.1 (2005) Inventory (categorical as determined by interval scale data). Finally, Hypothesis 6 looked at pre- and postassessment data for significant gains in learning after teachers completed the self-directed online web module using paired sample *t*-tests. With the methodology, variables, and instruments addressed, the results of this study can be shared.

Chapter 4: Results

This chapter presents and synthesizes the data captured to address the research questions in this study. The structure of this chapter begins with the presentation of the descriptive statistics concerning the demographic data of participants and then presents each research question and data associated with its respective hypothesis. The reliability and validity of instruments were discussed in the preceding methods chapter, as was the screening of the data. The data were checked for accuracy as the responses were gathered in accordance with the specific parameters for inclusion in the study. All responses were completed as they were required in the survey and found with the ranges expected. Response and completion rates for participants were also discussed in the methods chapter in the design collection procedure section. With these caveats extended, an examination of the demographics of participants begins the results data shared herein.

Participants' Demographic Information

From a population of 708 potential candidates, 85 participated in this study. Of those 708 teachers, 669 had valid emails making them eligible to receive the invitation. Seventeen of the 85 teachers completed multiple online surveys across different science content areas if they met the parameters for inclusion in the study, with two individuals not completing the survey once started. The demographics of gender, age, years teaching experience, grade levels taught, and teaching license credentials are presented.

Gender. Eighty-eight percent of participants (n=75) were female, and 12% (n=10) were male. This closely mirrors the national proportion of females to males teaching at the elementary level in U.S. public schools, which is 84% female and 16% male (Aud, et al., 2010).

Age of participants. Participant ages in years ranged from 27 to 62 years old. The ages of participants were clustered into groupings to mimic the group age ranges reflected in the 2010 National Center for Education Statistics most recent survey on the condition of education in the United States, which are: (a) less than 30 years old, (b) 30–39 years old, (c) 40–49 years old, (d) 50–59 years old, and (e) 60+ years (Aud, et al., 2010). The age ranges of participants mirrored those of the United States for those between ages 30 and 39 years, 50 and 59 years old, and 60+ years within 1 to 3% of the national averages. Teachers between ages 40 and 49 made up the largest percentage in the study (40.24%), which is larger than the national average at 23.9%. The smallest percentage of participants fell in the age range under 30 years old at 4.88%, which is less than the national average of 18.7% ([Table 4](#)) (Aud, et al., 2010).

Table 4
Age of Participants

		Participant Age				
		<i>F</i>	%	Valid %	Cumulative %	NCES %
Valid	Under 30	4	4.65%	4.88%	4.88%	18.7%
	30–39	23	26.74%	28.05%	32.93%	26.8%
	40–49	33	38.37%	40.24%	73.17%	23.9%
	50–59	19	22.09%	23.17%	96.34%	25.4%
	60+	2	3.49%	3.66%	100%	5.2%
Removed		4	4.65%	100%		100%
Total		86	100%			

Note. NCES data from the Condition of Education 2010 National Survey.

Years teaching experience. Table design recommendations suggest that there be an equal number of intervals between the ranges when reporting frequency distributions to avoid misinterpretation of the data (Rudestam & Newton, 2007). While a first analysis and presentation took this approach, the data were reformatted to mirror those ranges used by the National Center for Education Statistics 2010 report on the condition of U.S. education (Aud, et al., 2010). The ranges of teaching experience reflected in Table 5 similarly trend to those reflected at the national level in public elementary education, with the largest differences being nearly 37% of study participants have 4–9 years experience and slightly over 12% having 3 or fewer years experience.

Table 5
Years Teaching Experience of Participants

		Teaching Experience				
		<i>F</i>	%	Valid %	Cumulative %	NCES %
Valid	0–3	10	25.58%	12.20%	12.20%	17.0%
	4–9	30	26.74%	36.59%	48.79%	28.0%
	10–19	23	16.28%	28.05%	76.84%	27.9%
	20+	19	26.74%	23.16%	100%	27.0%
Removed		4	4.65%	100%		99.9%
Total		86	100%			

Note. NCES data from the Condition of Education 2010 National Survey.

Teaching license credentials. The largest category reported by teachers' self-reporting of teaching credentials were those holding an elementary preK–6 licensure at 56.1%, followed by 28% who reported they were middle level certified (Table 6).

Table 6
Breakdown of Teacher Licensure by Certification Type

Teacher Licensure		<i>F</i>	%	Valid %	Cumulative %
Valid	Elementary Education (preK–6)	46	53.49%	56.1%	56.10%
	Middle Education (6–8)	23	26.74%	28.0%	84.10%
	Secondary Science—General	5	5.81%	6.10%	90.20%
	Secondary Science—Life Science	2	2.33%	2.40%	92.60%
	Secondary Science—Earth/Space Science	1	1.16%	1.20%	93.80%
	Secondary Science—Physical Science	0	—	—	—
	Multiple Secondary Science Subject Endorsements	5	5.81%	6.10%	99.9%
Removed	4	4.65	100%		
Total	86	100%			

When looking at those teachers reporting any secondary science certificate, only 9.7% had this type of endorsement, with the largest percentage of these certificate holders holding a general secondary science designation (6%), and no one had an endorsement in physical science (Figure 4).

Teaching License for Current Teaching Credentials

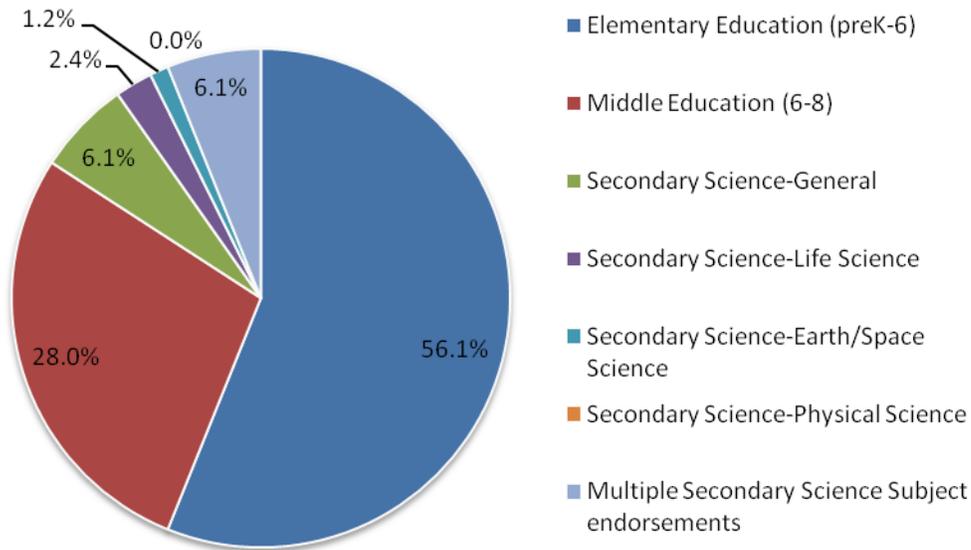


Figure 4. Participant percentages of different teacher licensures.

Grade levels taught. All teachers had to self-identify that they taught at least one of the four grades that was the focus of this study (i.e., grades three – six). After meeting this parameter and being accepted into the study, teachers self-identified the multiple grade levels they taught. Table 7 reflects this distribution where one can observe that 63% taught one of these four grade levels with the largest percentage of teachers identifying themselves as teaching grade 6 at 21%. Approximately 8% taught grades 1 or 2, 51% taught grades 1–5, and 29% taught grades 7 or 8.

Table 7
Grade Levels Taught by Participants

Grade Levels			
		Frequency	Percentage
Valid	1	6	3.4%
	2	9	5.1%
	3	20	11.2%
	4	22	12.4%
	5	33	18.5%
	6	37	20.8%
	7	22	12.4%
	8	29	16.3%
Removed		4	2.3%

Note: Multiple grade levels were requested to be checked with 178 total responses.

This data is corroborated when one reviews the licensure credential above, where 28% self-reported having a middle level teaching certificate (grades 6–8), and 56% reported having a preK–6 grade certificate. Thus the sixth grade may contain teachers from both elementary and middle school grade levels. Figure 5 shows the percentages by grade level with the overlapping endorsement percentages across grade levels. With the participant demographic data shared, the results as supporting each research question follows.

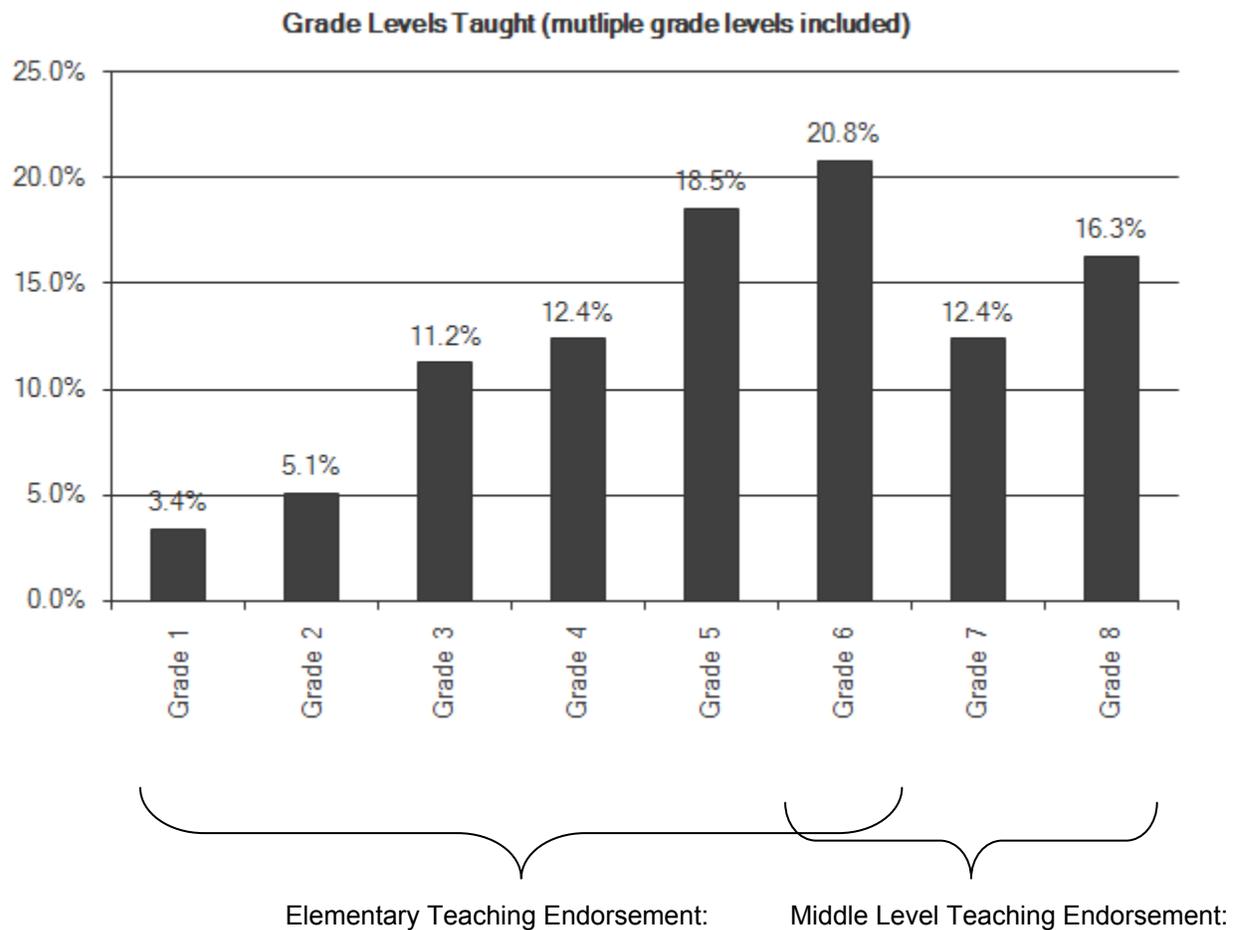


Figure 5. Percentage of grade levels taught by participants with elementary and middle level endorsements.

Teacher learning preferences. Teachers completed the 12-item Kolb LSI 3.1 (2005) to determine their learning style preference, which placed all 85 teachers into one of four categorical learning preferences: (a) diverging, (b) assimilating, (c) converging, and (d) accommodating. The participants were grouped into the four categories in the following frequencies: (a) assimilating: 26, (b) accommodating: 25, (c) converging: 23, and (d) diverging: 11. For the 17 teachers who took additional teacher content-interaction preference surveys for multiple science content areas, a single Kolb LSI 3.1 learning preference score was used for the

within-subjects analysis. Fifteen of the 17 teachers received an identical LSI preference on the second survey. For the two educators who received a score that was different than the previous two administrations of the Kolb LSI 3.1 (2005), the learning preference that was repeated in two of the three administrations was assigned, given it reflects a personal characteristic trait when administered. The main emphasis for the 17 teachers taking multiple surveys was reporting their preferences for the five different content-interaction strategies across the different science content areas addressed in the self-directed web module. The Kolb LSI 3.1 is a copyrighted commercial instrument, limiting the sharing of the instrument items and its scoring guide herein. Of the 85 participants, the teachers were nearly equally distributed across three of the four learning styles, with the diverging group containing approximately one-half of the other learning style group totals (i.e., 11 classified as diverging). For a review of the different Kolb learning styles, see [Appendix A](#) and Figure 3. With the demographic and learning preference classifications shared, a discussion of the research question and its supporting hypotheses follows.

Research Question

The research questions that guided this exploratory and descriptive study: Which features of on-demand, self-paced online professional development have the greatest import and learning value for elementary educators and how do they differ for online learners with varying characteristics, focusing specifically on learner-content interaction as described by Anderson's 2003 Equivalency of Interaction Theorem? The five following content-interaction strategies examined were: (a) interactive reference, (b) pedagogical implications, (c) hands-on activities,

(d) personalized feedback, and (e) simulations. To address this research question, six different hypothesis were formulated for analysis.

Age and Preferred Content-Interaction Strategies Correlated: H1

Based on the literature review in Chapter 2, it was predicted that age would be positively correlated with the type of preferred interaction desired in on-demand, self-directed web modules (e.g., simulation, interactive reference, hands-on, pedagogical implications, etc.), meaning as age increases, teachers' preferences for strategies such as interactive reference, and personal feedback would increase.

Results. The correlations between age and the five different learner-content interaction strategies appear in Table 8. Three of the five individual learner-content interaction strategies were positively correlated with age at a statistically significant level: (a) simulations, (b) personal feedback, and (c) interactive reference. The overall correlation between the simulation content-interaction strategy and age was statistically significant when the five learner survey preference questions were combined as a single index, $r(102) = .21, p = .03$, and the internal reliability or consistency for the five questions that combined to form this index was high, Cronbach $\alpha = .91$.

Table 8
Correlations Between Age and Preferred Content-Interaction Strategies: H1

Age and Content-Interaction Strategies Across Seven Science Content Areas

	Range of r_s		Overall Correlation Index
Simulations	.09 ($p = .33$)	.26 ($p = .03$)	$r(102) = .2, p = .03$
Hands-On Activities	.04 ($p = .54$)	.09 ($p = .34$)	$r(102) = .08, p = .45$
Personal Feedback	.09 ($p = .36$)	.24 ($p = .01$)	$r(102) = .20, p = .04$
Interactive Reference	.10 ($p = .30$)	.21 ($p = .04$)	$r(102) = .008, p = .02$
Pedagogical Implications	-.09 ($p = .34$)	.03 ($p = .76$)	$r(102) = .008, p = .94$

The range of correlations for each of the individual preference questions for the simulation interaction strategy ranged from low and nonsignificant to very strong and significant respectively, $r(102) = .09, p = .33$ to $r(102) = .26, p = .03$. The content-interaction strategy of personal feedback was statistically significant with age when the five learner survey preference questions were combined as a single index, $r(102) = .20, p = .04$, and the internal consistency for the five questions that formed this index was high, Cronbach $\alpha = .93$. The correlations for each of the five preference questions for the personal feedback interaction strategy ranged from nonsignificant to significant, $r(102) = .09, p = .36$ to $r(102) = .24, p = .01$. Finally, the interactive reference content-interaction strategy overall index was also statistically significant when the survey questions were combined, $r(102) = .22, p = .02$ and the internal consistency was also

high, Cronbach $\alpha = .94$. The correlations for the individual preference correlations for interactive reference ranged from very weak and nonsignificant to moderate and significant, $r(102) = .10, p = .30$ to $r(102) = .21, p = .04$.

Summary. Collectively, these results suggest that as age increases, preferences for three types of learner-content interaction strategies increase: (a) simulations, (b) personal feedback, and (c) interactive reference. Thus, as teachers increased in age, they indicated a higher preference for these types of content-interaction strategies in self-directed e-PD web modules.

Years Teaching Experience and Content Interaction Strategies Correlated: H2

Based on the literature review in Chapter 2, it was predicted that years teaching experience would be positively correlated with the type of preferred interaction desired in on-demand, self-directed web modules (e.g., simulation, interactive reference, hands-on, pedagogical implications, etc.) (del Valle & Duffy, 2009; Kayes, 2005; Schaller, et al., 2002).

Results. The correlations between years of teaching experience and the following five different learner-content interaction strategies were determined: (a) simulations, (b) hands-on activities; (c) personal feedback, (d) interactive reference, and (e) pedagogical implications (Table 9).

Table 9
Correlations Between Years Teaching Experience and Preferred Content-Interaction Strategies: H2

Years Teaching Experience and Content-Interaction Strategies

	Range of <i>r</i> s		Correlation
Simulations	.01 (<i>p</i> = .92)	.12 (<i>p</i> = .20)	$r(102) = .04, p = .67$
Hands-On Activities	.05 (<i>p</i> = .54)	.14 (<i>p</i> = .16)	$r(102) = .11, p = .29$
Personal Feedback	.21 (<i>p</i> = .03)	.28 (<i>p</i> = .005)	$r(102) = .27, p = .006$
Interactive Reference	.10 (<i>p</i> = .29)	.27 (<i>p</i> = .007)	$r(102) = .22, p = .02$
Pedagogical Implications	-.006 (<i>p</i> = .95)	-.17 (<i>p</i> = .08)	$r(102) = -.08, p = .41$

Two individual learner-content interaction strategies were found to positively correlate with years teaching experience: (a) personal feedback, and (b) interactive reference. The overall correlation between the personal feedback content-interaction strategy and years experience was statistically significant when the five learner survey preference questions were combined as a single index, $r(102) = .27, p = .006$, and the internal reliability or consistency for the five questions that combined to form this index was high: Cronbach $\alpha = .93$. The correlations for each of the individual preference questions for the personal feedback interaction strategy were all significant ranging from $r(102) = .21, p = .03$ to $r(102) = .28, p = .005$. The content-interaction strategy of interactive reference was statistically significant with years of teaching experience when the five learner survey preference questions were combined as a single index: $r(102) = .22,$

$p = .02$, and the internal reliability for the five questions that formed the index was high: Cronbach $\alpha = .94$. The correlations for the individual preference correlations for interactive reference ranged from nonsignificant to significant, $r(102) = .10, p = .29$ to $r(102) = .27, p = .007$ (Table 9).

Summary. These results suggest that years of teaching experience is related to learner preferences, and as experience increases, preferences for personal feedback and interactive reference learner-content interaction strategies also increases. (i.e., teachers with more experience indicated a higher preference for strategies that involve descriptive feedback from multiple-choice questions and engagement with online content via check-your-thinking mouse-overs, audio narration, and animations to facilitate understanding).

Age and Learning Achievement Positively Correlated: H3

It was predicted that age would be positively correlated with achievement as measured via a pre- and postassessment and final assessment for those who have completed and passed the online self-directed web-based module (del Valle & Duffy, 2009; Hoskins & van Hooff, 2005; Kayes, 2005). Older teachers may take their PD more seriously and apply more effort (del Valle & Duffy, 2009; Hoskins & van Hooff, 2005; Schaller, et al., 2007).

Results. The correlations between age and learning achievement are given in Table 10. The pretest/posttest learning assessment instruments across all seven content areas are highly correlated with the same instruments being administered for each respective science content area before and after a teacher completes a web module, $r(102) = .48, p = .001$. This same instrument is also correlated at a statistically significant level with the final postassessment instruments for each science content area, $r(102) = .42, p = .001$. This corroborates the use of these instruments for this analysis as discussed in more detail in the instrumentation section of Chapter 2 and

Appendix G. The overall correlation between age and learning achievement between the pretest or posttest was not significant: pretest–age, $r(102) = .02, p = .85$; posttest–age, $r(102) = .08, p = .45$. Similarly the correlation between age and learning achievement on the final assessment was not significant, $r(102) = .17, p = .08$.

Summary. The results above suggest that there is no correlation between age and the pretest or posttest across the seven science content areas examined, but there is a marginal correlation between age and the final assessment. As age increased, scores on the final assessment also increased, but not at a level that met the test of statistical significance.

Table 10
Correlations Between Age, Years Teaching Experience and Learning Achievement: H3 and H4

Age, Years Experience, Pre- and Postassessments and Final Assessments

	Pretest	Posttest	Final Assessment
Age	$r(102) = .02, p = .85$	$r(102) = .08, p = .45$	$r(102) = .17, p = .08$
Years Experience	$r(102) = -.07, p = .47$	$r(102) = .15, p = .12$	$r(102) = .22, p = .03$
Correlation between learning achievement assessments ^a			
Pretest–Posttest	$r(102) = .48, p = .001$		
Pretest–Final Assessment	$r(102) = .22, p = .02$		
Posttest–Final Assessment	$r(102) = .42, p = .001$		

Note. a. Pretest-Posttest is same instrument and different from final assessment instrument. All correlations are two-tailed with $df = 102$

Years Teaching Experience and Learning Achievement Positively Correlated: H4

It was predicted that years of teaching experience would be positively correlated with achievement as measured via a pre- and postassessment and final assessment for those who had completed and passed the online self-directed web-based module (del Valle & Duffy, 2009; Kayes, 2005; Russell, et al., 2009).

Results. The correlations between years teaching experience and learning achievement appear in Table 10. The correlation between years teaching experience and learning achievement between the pretest and the posttest was not significant: years experience–pretest, $r(102) = -.07$, $p = .47$; years experience–posttest, $r(102) = .15$, $p = .12$. The correlation between years teaching experience and learning achievement on the final assessment was significant, $r(102) = .22$, $p = .03$. Recall in Chapter 3, the pre- and postassessments for each science content area had a high internal consistency, with Cronbach α 's ranging from .609 to .882 (Appendix G), and all three assessments, including the final exam were highly correlated with each other (Table 11), ensuring their utility and reliability as instruments for this study: pretest–posttest, $r(102) = .48$, $p = .001$; pretest–final assessment, $r(102) = .22$, $p = .02$; posttest–final assessment, $r(102) = .42$, $p = .001$).

Summary. The results above suggest that there is no correlation between years of experience and the pretest or posttest across the seven science content areas examined, but there is a significant correlation between years teaching experience and the final assessment. As years experience increased, scores on the final assessment also increased. Passing the final assessment at the end of the web module was the trigger that awarded a certificate of competency and completion from the NSTA. The pretest and posttest did not carry this same weight.

Content-Interaction Strategy Matches Preferred Learning Style: H5

It was predicted that adult learners would prefer an online interaction type that would match their individual learning style over one that does not when accessing online, self-directed learning that focuses on learner-content interaction as the primary vehicle for learning (Farahani, 2003; Harlen & Doubler, 2004; Krall, et al., 2009; Lapointe & Reisetter, 2008; Rhode, 2009; Schaller, et al., 2007; Su, et al., 2005).

1. Teachers ranking interactive reference content most favorable (i.e., science content narrative, audio, images, animations, and glossary) will be identified with the Kolb (2005) assimilating learning style.
2. Teachers with the accommodating learning style will select hands-on activities as their preferred learner-content interaction strategy.
3. Those teachers identified with the converging learning preference will favor the simulations and pedagogical implications as their preferred interaction strategy.
4. Those ranking the personal feedback component (embedded follow-up questions and end-of-unit formative quizzes) as most favorable will be identified with Kolb diverging learning preference.

It was also predicted that pedagogical implications would be least preferred across all the learning styles with the exception of the Kolb converging learning style given it is the least interactive content strategy of the five being examined (e.g., only narrative text with no type of engagement, mouse-overs to check your thinking, multiple-choice questions, slide shows, etc.). For a review of the aggregated learner survey frequency distribution preferences for each content-interaction strategy, see [Appendix J](#).

Results. First a general overall review of the results is presented, and then each learning style is examined in finer detail. [Table 11](#) lists the aggregated mean preference scores for

teachers across each Kolb LSI 3.1 Learning Style (2005). Teacher means are determined by averaging preference responses across the five-item survey for all seven science content areas: (a) facilitates engagement, (b) facilitates learning content, (c) facilitates content retention, (d) facilitates teaching science, and (e) desiring more of this content-interaction type. For learners classified in three of the four learning style categories, pedagogical implications (PI) were the least preferred content-interaction strategy: assimilating, $PI M = 3.58, SD = 1.39$; accommodating, $PI M = 3.41, SD = 1.39$; converging, $PI M = 3.32, SD = 1.65$. As reflected in Tables 13–15, these differences were statistically significant: assimilating, $F(4,116) = 13.40, p < .001$; accommodating, $F(4, 116) = 20.33, p < .001$; converging, $F(4, 116) = 11.81, p < .001$. Teachers classified with a diverging learning style did not prefer any learning content interaction strategy more than another: $F(4, 116) = .41, p < .80$. With a view of the overall results briefly examined, a look at the individual predilections for individual learning preferences to specific learner-content interaction strategies follow.

Table 11
Learning Style Comparisons to Content-Interaction Strategies: H5

Learning Style	Content-Interaction Strategy	N	Mean	SD
Assimilating Group n = 26	Simulation	85	4.90	.91
	Hands-On	85	4.74	1.05
	Personal Feedback	85	4.87	.96
	Interactive Reference*	85	4.91	.85
	Pedagogical Implications	85	3.58	1.39
Accommodating Group n = 25	Simulation	85	4.98	1.02
	Hands-On*	85	5.14	.89
	Personal Feedback	85	4.64	1.12
	Interactive Reference	85	4.98	.88
	Pedagogical Implications	85	3.41	1.39
Converging Group n = 23	Simulation*	85	4.99	.95
	Hands-On	85	5.18	1.33
	Personal Feedback	85	4.77	1.27
	Interactive Reference	85	4.98	1.20
	Pedagogical* Implications	85	3.32	1.65
Diverging Group n = 11	Simulation	85	4.96	1.07
	Hands-On	85	4.55	1.66
	Personal Feedback*	85	4.46	1.14
	Interactive Reference	85	4.75	1.43
	Pedagogical Implications	85	4.49	1.72

Note: *Predicted Content-Interaction Strategy Preference for each Learning Style. Learning Style Preferences from Kolb LSI 3.1 (2005)

Teachers selecting the assimilating learning style were predicted to rate the interactive reference (IR) content-interaction strategy as their most preferred strategy. As shown in [Table](#)

11, interactive reference was rated as the most preferred strategy ($M = 4.91, SD = .85$), though mean differences for IR and three other interaction strategies (i.e., personal feedback, simulations, and hands-on) were small and not significantly different (Table 12). Pedagogical implications was the least preferred content-interaction strategy at a statistically significant level, $F(4,116) = 13.40, p < .001$. Statistical significance was still apparent after applying a Geisser Greenhouse correction for violation of sphericity (Pedhazur & Schmelkin, 1991), $F(2.73, 79.24) = 13.40, p < .001$. *A priori*/LSD mean comparisons revealed the pedagogical implications interaction strategy was least preferred at a statistically significant level with each of the other four interaction strategies at $p < .01$ (Table 12).

Table 12
Assimilating: a Priori/LSD Mean Comparison Differences

Omnibus F (test of within-subject effects): $F(4, 116) = 13.40, p < .001$			
Measure 1	Measure 2	Mean Difference	p -value significance level
Simulation	Hands On	-.16	.37
Simulation	Personal Feedback	-.03	.84
Simulation	Interactive Reference	.006	.96
Simulation	Pedagogical Implications	-1.32	.001
Hand's On	Personal Feedback	.13	.60
Hand's On	Interactive Reference	.17	.37
Hand's On	Pedagogical Implications	-1.16	.001
Personal Feedback	Interactive Reference	.04	.80
Personal Feedback	Pedagogical Implications	1.33	.001
Interactive Reference	Pedagogical Implications	1.33	.001

Teachers classified with the Kolb LSI 3.1 (2005) as accommodating learning style were predicted to rate the hands-on content-interaction strategy as their most preferred strategy. As shown in [Table 11](#), hands-on was rated as the most preferred strategy ($M = 5.14, SD = .89$), though mean differences for hands-on and three other interaction strategies (i.e., interactive reference, simulations, and personal feedback) were small and not significantly different (statistically) ([Table 13](#)). Pedagogical implications was the least preferred content-interaction strategy at a statistically significant level, $F(4,116) = 20.33, p < .001$. Statistical significance was still apparent after applying a Geisser Greenhouse correction, $F(2.98, 86.89) = 20.33, p < .001$. A *priori*/LSD mean comparisons revealed the pedagogical implications interaction strategy was least preferred at a statistically significant level with each of the other four interaction strategies at $p < .01$ ([Table 13](#)).

Table 13
Accommodating: a Priori/LSD Mean Comparison Differences

Omnibus F (test of within-subject effects): $F(4,116) = 20.33, p < .001$			
Measure 1	Measure 2	Mean Difference	p -value significance level
Simulation	Hands On	-.16	.26
Simulation	Personal Feedback	-.35	.14
Simulation	Interactive Reference	.00004	1.0
Simulation	Pedagogical Implications	-1.57	.001
Hands On	Personal Feedback	-.51	.01
Hands On	Interactive Reference	-.16	.35
Hands On	Pedagogical Implications	-1.73	.001
Personal Feedback	Interactive Reference	.35	.12
Personal Feedback	Pedagogical Implications	-1.22	.001
Interactive Reference	Pedagogical Implications	-1.57	.001

It was predicted that the converging learning style teachers would most prefer pedagogical implications and simulation content-interaction strategies. As shown in [Table 11](#), hands-on and simulation were the most preferred strategies (hands-on $M = 5.18$, $SD = .1.33$; simulation $M = 4.99$, $SD = .95$), though mean differences for these two strategies and two other interaction strategies (i.e., personal feedback and interactive reference) were small and not significantly different from each other ([Table 14](#)). Pedagogical implications was the least preferred content-interaction strategy at a statistically significant level of the test within subjects, $F(4,116) = 11.81$, $p < .001$. Significance was still apparent after applying a Geisser Greenhouse correction, $F(2.13, 55.48) = 11.81$, $p < .001$. A priori mean comparisons revealed that the pedagogical implications interaction strategy was least preferred at a significant level in each of the other interaction strategy types at $p < .01$ ([Table 14](#)).

Teachers classified in the diverging learning style via the Kolb LSI 3.1 (2005) were predicted to prefer the personal feedback content-interaction strategy more than the other four interaction strategies. [Table 11](#) reveals simulation as the most preferred strategy ($M = 4.96$, $SD = 1.07$) for those with diverging learning styles, but the mean differences among the five content-interaction strategies were small and not significantly different, $F(4,116) = .41$, $p < .80$. The Geisser Greenhouse correction confirms the same, $F(1.94, 17.92) = .41$, $p < .001$. Those with the diverging learning style did not prefer any one interaction strategy over any other at $p < .01$ ([Table 15](#)).

Table 14
Converging: a Priori/LSD Mean Comparison Differences

Omnibus F (test of within-subject effects): $F(4,116) = 11.81, p < .001$

Measure 1	Measure 2	Mean Difference	p -value significance level
Simulation	Hands On	.19	.25
Simulation	Personal Feedback	-.22	.29
Simulation	Interactive Reference	-.007	.98
Simulation	Pedagogical Implications	-1.67	.001
Hands On	Personal Feedback	-.41	.05
Hands On	Interactive Reference	-.20	.58
Hands On	Pedagogical Implications	-1.86	.001
Personal Feedback	Interactive Reference	.21	.42
Personal Feedback	Pedagogical Implications	-1.45	.001
Interactive Reference	Pedagogical Implications	-1.66	.001

Table 15
Diverging: a Priori/LSD Mean Comparison Differences.

Omnibus F (test of within-subject effects): $F(4,116) = .41, p < .80$

Measure 1	Measure 2	Mean Difference	p -value significance level
Simulation	Hands On	-.41	.43
Simulation	Personal Feedback	-.51	.08
Simulation	Interactive Reference	-.21	.53
Simulation	Pedagogical Implications	-.47	.28
Hands On	Personal Feedback	-.09	.88
Hands On	Interactive Reference	.20	.76
Hands On	Pedagogical Implications	-.05	.89
Personal Feedback	Interactive Reference	.29	.35
Personal Feedback	Pedagogical Implications	-.04	.94
Interactive Reference	Pedagogical Implications	-.25	.68

Summary. Teachers were classified into one of four different learning styles (A. Y. Kolb & Kolb, 2005) and predictions were made regarding their preferences for five particular learner-content interaction strategies as measured individually and as an overall index, averaging means across seven different content areas. For learners classified in three of the four learning style

categories, pedagogical implications (PI) was the least preferred content interaction strategy: assimilating, $PI M = 3.58, SD = 1.39$; accommodating, $PI M = 3.41, SD = 1.39$; converging, $PI M = 3.32, SD = 1.65$. These differences were statistically significant: assimilating, $F(4, 116) = 13.40, p < .001$; accommodating, $F(4, 116) = 20.33, p < .001$; converging, $F(4, 116) = 11.81, p < .001$ (Tables 13–15 respectively). Teachers classified with a diverging learning style did not prefer any learning content interaction strategy more than another, $F(4, 116) = .41, p < .80$ (Table 16).

Teachers' Learning Gains With Self-Directed Web Modules: H6

The last hypothesis predicted that teachers completing and passing the 10-hour self-directed web modules would demonstrate gains in learning. Comparisons with both the pre- and posttest and the pretest and final assessment follow. First, participant scores from each respective pretest, posttest, and final assessment were subjected to a paired sample *t*-test to determine if the online modules successfully supported teacher increased understanding of the key science concepts addressed across the seven different science content web modules.

Results. The results in [Table 16](#) show that teachers scored higher on the posttest ($M = 82.39, SD = 7.04$) than on the pretest ($M = 61.31, SD = 18.45$), and [Table 17](#) reveals it was at a level that was significant, $t(101) = 11.63, p < .001$. Similarly, teachers scored higher on the final assessment ($M = 79.14, SD = 12.91$) than on the pretest ($M = 61.31, SD = 18.45$) ([Table 16](#)), and at a significant level, $t(101) = 10.84, p < .001$ ([Table 17](#)). The pretest, posttest, and final assessment at the end of each web module were all statistically correlated with each other, ensuring a coherence between measurement instruments: pretest–posttest $r(102) = .22, p = .027$; pretest–final assessment $r(102) = .48, p = .000$ ([Table 18](#)).

Table 16
Paired Sample Descriptive Statistics for Teacher Learning Gains With Self-Directed Web Modules

Paired Sample Statistics					
Pair		N	Mean	SD	Standard Error Mean
Pair 1	Pretest	102	61.31	18.45	1.83
	Posttest	102	82.39	7.40	.73
Pair 2	Pretest	102	61.31	18.45	1.83
	Final Assessment	102	79.14	12.91	1.28

Table 17
Paired Sample t-Tests for Teacher Learning Gains With Self-Directed Web Modules

Paired Samples	N	Mean	SD	t	df	p
Pretest–Posttest	102	21.09	1.81	11.63	101	.000
Pretest–Final Assessment	102	17.84	16.62	10.84	101	.000

Note: All tests are 2-tailed.

Table 18
Paired Samples Correlations for Pretest, Posttest, and Final Assessment

Paired Sample Correlations				
Pair		N	Correlation	p
Pair 1	Pretest and Posttest	102	.220	.027
Pair 2	Pretest and Final Assessment	102	.484	.000

Summary. Teachers' posttests and final assessment mean scores across the seven science content areas were higher than their respective mean scores on the pretests, and at a level that was significant (Table 17). Thus, on two separate instruments teachers showed statistically significant growth in learning the science concepts that were addressed in the self-directed web modules. Both of these results were significant at $p < .001$, which means that the likelihood that the results are due to change alone is far less than 1%. Be that as it may, one cannot necessarily contribute the learning gains achieved to the treatment of the web modules alone, as this study did not apply a random assignment design for this descriptive, exploratory study. With the results shared a discussion of the findings and their implications is now merited.

Chapter 5: Discussions, Summary, Conclusions, and Implications

This chapter shares the overall contributions of this study, presents a discussion and summary findings, and closes with conclusions and implications for future research.

Study Contributions

This study was conducted to explore elementary teacher preferences for and perceptions of self-directed electronic professional development for a nonrandomized judgment sample of 85 teachers in grades three – six who completed and passed 10-hour on-demand web modules across seven science content areas. This study is in response to researchers' growing interest in and focus on professional development (Banilower, et al., 2007; Council of Chief State School Officers, 2008; Garet, et al., 2001; Penuel, et al., 2007; Supovitz & Turner, 2000; K. S. Yoon, et al., 2008) as a way to ameliorate U.S. lagging scores on both national and international student achievement studies (Augustine, et al., 2010; Bybee, 2008; Organization for Economic Co-operation and Development, 2007; U.S. Department of Education, et al., 2008; US Department of Education, et al., 2007). These lagging student scores in part are coupled with a need to support elementary educators improved science content knowledge (Banilower, et al., 2006; Council of Chief State School Officers, 2007a; Horizon Research, 2001; Shallcross, Spink, Stephenson, & Warwick, 2002). Across the United States, tens of thousands of educators are assigned to teach a science content area for which they have no major or certification (Council of Chief State School Officers, 2007b; U.S. Department of Education, 2004). Unfortunately, the magnitude of this challenge for elementary educators lies in providing support at a level that is scalable and sustainable for our nations' 1.9 million elementary teachers of science (Aud, et al., 2010). This issue of scale is exacerbated when one considers the cost of learning through face-to-face delivery models alone, thus calling for research that explores models and methodologies in

online self-directed learning (Dede, 2006; Dede, et al., 2009; Russell, et al., 2009; Shallcross, et al., 2002). In that regard, this study explored a self-directed model of electronic professional development (e-PD) and sought to understand what types of interaction strategies are of greatest learner satisfaction and provide the highest learning impact for teachers in grades three – six. Employing Anderson’s Equivalency of Interaction Theorem as the theoretical backdrop, it suggests that if adequate richness is provided in one of three interaction strategies online, the other two may be offered in diminished capacities and still facilitate a worthwhile learning experience (T. Anderson, 2003). The three interactions Anderson espouses are learner-learner interaction, (b) learner-instructor interaction, and (c) learner-content interaction (T. Anderson, 2003). Looking at the variables of age and years teaching experience as supported by the literature (del Valle & Duffy, 2009; Hoskins & van Hooff, 2005), this quantitative descriptive study explored teachers’ preferences for five different types of online content-interaction strategies: (a) simulations, (b) interactive reference, (c) hands-on, (d) personal feedback, and (e) pedagogical implications, which also supports others’ work in self-directed online learning (Russell, et al., 2009; Schaller, et al., 2002; Schaller, et al., 2007; Whitaker, et al., 2007). This study enlightens instructional designers regarding which features of self-directed e-PD content are worthwhile for development from both learning efficacy and educator preference viewpoints. Educator administrators will also be informed as they make decisions regarding the type of professional development opportunities selected for those teachers they support. With the groundwork laid for the contributions of this study, a discussion of the findings ensues, revisiting the overarching research question and the six hypotheses that guided data collection and analysis.

Discussion of Findings

The overarching research question focused on which features of on-demand, self-paced online professional development have the greatest import and learning value for elementary educators and how do they differ for learners with varying characteristics (i.e., age, years teaching experience, and learning preferences)? The five following content-interaction strategies examined were: (a) interactive reference, (b) pedagogical implications, (c) hands-on activities, (d) personalized feedback, and (e) simulations.

Age and content-interaction strategies. The first relationship examined was teacher age as related to the five online learner content-interaction strategies. Several studies find age affecting learning preferences among adults (Schaller, et al., 2002; Schaller, et al., 2007), and some report age as a predictor of achievement (Hoskins & van Hooff, 2005). This study predicted age would be positively correlated with online learning content-interaction strategies. Three unique content-interaction strategies were found to positively correlate with age at a significant level: (a) simulations, (b) personal feedback, and (c) interactive reference. This seems plausible as simulations and their value in learning science concepts is well documented (Bayraktar, 2001; Cameron, 2003; Kali & Linn, 2008; K. M. Lee, et al., 2004; Mayer & Moreno, 2002; Reed & Jazo, 2002; Renkl & Atkinson, 2002; Schnotz & Rasch, 2005). Personal feedback and interactive reference are both worthwhile learner-content interaction strategies in support of inquiry-based learning for science as described in the educational technology literature (Kali & Linn, 2008; Narciss, 2008; Shute & Zapata-Rivera, 2008). From an instructional design perspective the personal feedback interaction strategy draws on the literature discussing the value of providing immediate and elaborate external feedback for self-regulated learning that facilitates error detection and insight regarding the concept at hand (Narciss, 2008). Similarly, simulation

and interactive reference interaction strategies are espoused in the literature to support technology-enhanced inquiry-based learning (Kali & Linn, 2008), and are part of a growing body of research in adaptive technology environments (Shute & Zapata-Rivera, 2008). These findings seem to support those of Schaller, et al. (2002), who similarly found adult learners favoring interactive reference and simulation interaction strategies over role-playing opportunities (which were more preferred among young learners). In a later study by Shaller et al. (2007), the types of learning preferences were refined for adults, and confirmed significant differences between adult and children's preferences for web-based content. The age range for participants in this study focused on adult learners with 63% between 40 and 59 years of age. Others have found relationships between age and effort applied in self-directed online learning, reporting that as age increased, so did the level of activity online (Hoskins & van Hooff, 2005). Although, the Hoskins and van Hoff (2005) are cautious to note that the increased activity may be more a factor of motivation than age, and their sample included 110 undergraduate students, where only 5 students were 30 years or older. Thus, caution should apply in generalizing these relationships. In surveying approximately 1,200 adults expressing their preferences for different types of content-interaction strategies, Schaller et al. (2007) found significant differences in preference strategies related to an individual's learning style using Kolb's LSI 3.1 (2005) and age. They state "learning style *does* influence an individual's preferences for learning activities, particularly among adults. For example, adult social learners [accommodating style] prefer role-play activities while intellectual learners [assimilating style] prefer reference-style presentations" (Schaller, et al., 2007). Their analysis found the relationship between learning styles and content-interaction preferences stronger in adults, with assimilating learning style adults preferring interactive reference, accommodating learning style adults preferring role-play interaction, and

converging learning style adults preferring puzzle-mystery types of activities (Schaller, et al., 2007).

Conversely, del Valle and Duffy (2009) in their examination of 59 self-enrolled teachers consuming self-paced online PD, found no significant difference regarding age across three distinct teaching clusters of participants: (a) mastery-oriented teachers, (b) task-focused teachers, and (c) teachers contributing a minimalist effort. Their convenience sample included 24 elementary educators and 25% of the overall sample identified themselves between the ages of 36 and 45 years old. For this study 28% of the 85 self-selected participants fell between the ages of 30 and 39 years, and 40% between the ages of 40 and 49 years with elementary-certified educators (preK–6) making up 56% of the sample. Only 4.88% of the teachers in this study were under 30 years of age (Table 4), and as such, this should be taken into consideration when interpreting these findings.

From the results of this study, there seems to be some relationship between age and self-directed content-interaction strategies that involve cognitive engagement (i.e., simulations where the learner may control and observe the relationship between variables), and the supportive feedback provided by interactive reference and personal feedback content-interaction strategies (e.g., check-your-thinking mouse-overs, multiple-try, and answer-until-correct multiple-choice questions, and slideshows supported with question prompts, etc.). Appendix C provides descriptions and examples of these types of content-interaction strategies.

Years teaching experience and content-interaction strategies. The next relationship examined was years teaching experience as related to the five online learner-content interaction strategies. Several recent studies find significant differences in learning preferences that may be attributable to varied work experience (del Valle & Duffy, 2009; Kayes, 2005). This study

predicted that years teaching experience would be positively correlated with interaction strategies and found two strategies correlated at a significant level: (a) personal feedback, and (b) interactive reference (Table 9). As discussed in their examination of self-enrolled teachers consuming online PD, del Valle and Duffy's (2009) primary research goal was to understand the characteristics of the teachers, given various online learning constraints and affordances. Their goal in part was to relate the demographic characteristic of the teachers against the backdrop of their work efforts with the hopes of identifying "distinctive patterns in support of effective online learning experiences, thus informing future instructional design methodologies" (p. 130). They found three significantly distinct clusters of teachers completing self-paced online PD: (a) mastery-oriented, (b) task-oriented, and (c) minimalist. Separate one-way ANOVAs and a post-hoc Tukey analysis found teachers classified as mastery-oriented with significantly more years teaching experience compared with task-oriented learners. No significant difference was found with those classified in the minimalist group. The researchers posit that teachers in both the mastery and task-oriented groups spent a significantly larger portion of time in the resources and reviewed a larger portion of the resources available compared to the minimalist group. It seems plausible as purported by del Valle and Duffy (2009) that teachers with more years experience may have more time to dedicate to their learning and have a stronger framework of knowledge for exploring their learning more deeply, while those with fewer years of experience have less of both, and as such, work through the resources with equal vigor but in more condensed timeframes. For elementary teachers this seems supported by the longitudinal research of Mulholland and Wallace (2005), which followed the 10-year career of an elementary teacher from preservice to established teacher. They found during the beginning inservice years for this grade six elementary teacher, her ability to develop general pedagogical classroom management

skills and knowledge of students was paramount for effective teaching and until developed, limited the growth opportunity for science subject matter knowledge (Mulholland & Wallace, 2005).

Similarly, Kayes (2005) in validating the Kolb LSI 3.1 learning preference instrument looked across 221 undergraduate and graduate students and found statistically significant differences between these two groups on learning preferences. Kayes (2005) hypothesized that the differences could be attributable to work experience or age, but cautioned that more research was needed to support these assertions due to an uneven sample size. In this study, the individual content-interaction strategies of interactive reference and personal feedback were found correlated at a significant level for years experience, so there appears to be some credence that more senior teachers (whether classified by age or years experience) do have unique preferences for different types of self-directed learning strategies. This is not conclusive, but the research cited above appears to support these findings. Thus, embedding engagement opportunities such as multiple-choice questions that provide rich descriptive feedback as progressing through web modules may enhance adult engagement levels for learning. Other researchers espouse the importance of providing avenues for elementary teachers to increase their subject matter knowledge, which in many cases is limited only to what is provided in prescribed curriculum materials (Mulholland & Wallace, 2005). Given this is an exploratory study using a judgment sample, findings are limited to those participating in this study, but an examination of age and years experience as correlated with learning achievement follows.

Age, years teaching experience, and learning achievement. The variables of age and years teaching experience may be related in this study, as 51% of participants reported having between 10 and 20+ years experience, and 63% were between 40 and 59 years of age, thus these

variables will be conjoined for the purposes of this discussion. As shown in Table 10, age and learning achievement were not correlated with the pretest or posttest but did approach significance for the final assessment: $r(102) = .17, p = .08$. The correlation between years teaching experience and learning achievement between the pretest or posttest was also not significant, but the correlation between years teaching experience and learning achievement on the final assessment was significant, $r(102) = .22, p = .03$. As mentioned in the results section, this may be due in part to the incentive awarded if the final assessment is passed (e.g., receipt of continuing education credits, graduate hours, or teacher remuneration). With this in mind, how do these findings relate to the literature that looked at similar variables?

Del Valle and Duffy (2009) looked at teachers completing self-paced online professional development and similarly did not find age as a significant factor across three different clusters of learners. Although, learning achievement in their study was not captured through a knowledge assessment, but instead it was reported through teachers' self-reported perceptions of learning. Students in all three clusters rated their learning and transfer of knowledge to the classroom very high, which del Valle and Duffy (2009) cite as a ceiling effect, and all but one of the 59 participants passed the online PD module. Del Valle and Duffy claim this supports the notion that online self-directed learning environments may be worthwhile for all types of educators if they self-select participation in PD experiences and the content is professionally meaningful. Del Valle and Duffy (2009) report their findings are inconsistent with prior claims that learners with a modest amount of existing subject matter knowledge would have the highest chance for mastery, avoiding boredom. They instead suggest that self-directed learning environments, quality online resources, and the context for learning are intertwined to support content knowledge learning. This supposition is buttressed by others making similar claims about the

importance of aligning the resources, context, pedagogy, and technology (Mentis, 2008). It also underpins the need for this study and is espoused by others who posit the importance of PD linked to teachers' individual needs at various stages of their careers (L. Anderson & Olsen, 2006; Mulholland & Wallace, 2005; Mushayikwa & Lubben, 2009).

Interestingly, the significant and positive findings of achievement in an online course for 231 middle level educators randomly assigned to one of four treatment groups—where one of the groups focused on self-directed learning with no moderated instructor or peer-to-peer interaction—found no significant difference in learning outcomes between the self-directed group and the other four groups (Russell, et al., 2009). In the study, Russell et al. (2009) discuss how ironically the “literature emphasizes the importance of facilitation, but our results showed no differences in learning outcomes between conditions that were highly facilitated by both a content expert and an online learning facilitator and those that lacked one or both of these types of support” (p. 462). The participants in the Russell et al. study (2009) had 48% younger than 40 years old. For years teaching experience, 38% had between 5 and 15 years experience, 29% more than 15 years, and 28% had taught fewer than 5 years, thus it would seem to indicate a fairly evenly dispersed group of educators. Caution should be applied to these findings, as 46% of the participants dropped out of the course according to the following percentages: (a) 53% from the highly supported group, (b) 41% from the facilitated peer support group, (c) 45% from the instructor-only supported group, and (d) 44% from the nonsupported group. Reasons for dropping the course included the following: (a) health and family issues, (b) too strenuous a time commitment in light of other competing priorities, and (c) technological barriers to access.

Hoskins and van Hooff (2005) analyzed age and achievement for students using several self-directed and voluntary features in an online environment (e.g., online quizzes, discussion

board usage, etc.) and found no significant gains between age and achievement. The ages for the vast majority of the 110 participants were under 30 years old, with only 4 participants over 30 years old. Although, similar to del Valle and Duffy (2009), age was positively correlated with “meaning orientation” ($r = 0.234, p < 0.05$), “indicating that with age students appeared to have developed a deeper approach of studying and a higher intrinsic motivation” (p. 182). Thus the independent variable of age as correlated with learning achievement is mixed. Given this study did not find age significantly correlated with learning achievement but did find years teaching experience and learning achievement (as measured via a final assessment) significantly correlated, what relationships between content-interaction strategies and preferred learning styles might lend additional insight to these findings?

Content-interaction strategy matches preferred learning style. This study sought to expand upon prior research analyzing learning styles that were derived and built upon Kolb’s Experiential Learning Theory (ELT), which espouses six propositions for learning. Succinctly abbreviated, four of the six propositions follow: (a) it is an iterative process that incorporates feedback for learning improvement, (b) it incorporates learners’ beliefs and understandings allowing them to test and refine their knowledge, (c) it involves the juxtaposition between concrete experiences and abstract conceptualization, and reflective observations and active experimentation, and (d) it engages the individual through the environment involving accommodation of new concepts and assimilation with existing understandings (D. A. Kolb, 1984). ELT claims an individual’s learning style and the overall learning context affect the process of learning and may vary with the learning task. Kolb’s theory generated an instrument that places learners in one of four discrete learning styles: (a) assimilating, (b) accommodating, (c) diverging, or (d) converging (A. Y. Kolb & Kolb, 2005). Figure 3 succinctly depicts the

learning preferences each of these styles support. Overarching this theory is that of Anderson's Equivalency of Interaction (2003), which claims that if one of the three types of interaction common in online learning are rich (i.e., learner-learner, learner-instructor, learner-content), the other two may be offered in a diminished capacity, thus affording efficiencies in consumption as related to scale and sustainability.

Based on the work of others examining interaction strategies and learning preferences (Felder & Brent, 2005; Hoskins & van Hooff, 2005; Kayes, 2005; Schaller, et al., 2002; Schaller, et al., 2007) and the science and mathematics online PD literature (Asbell-Clarke & Rowe, 2007; Harlen & Doubler, 2007; Krall, et al., 2009; Rhode, 2009), it was predicted that adult learners would prefer an online content-interaction strategy that matched their individual learning style. Results found partial support for these predictions in three of the four learning styles: (a) assimilating, (b) accommodating, and (c) converging. While in each of these three learning styles, learners' highest rated content-interaction strategy preference did match what was predicted, it was not at a level that was significantly different when compared against the other content-interaction strategies (e.g., simulations, hands-on, personal feedback, interactive reference, and pedagogical implications). This research corroborates the findings of Schaller et al. (2007), who also found that those with the assimilating learning style preferred interactive reference as a content-interaction strategy. For those identified with a diverging learning preference in this study, no content-interaction strategies were found more favorable than any other. Thus the prediction that personal feedback would be the most-preferred content-interaction strategy for those classified with a diverging learning style was not supported. This may be in part because only 11 participants comprised this group, thus making differences between their interaction preferences difficult to discern statistically (Pedhazur & Schmelkin, 1991). One

prediction was confirmed at a level of significance. Across three of the four Kolb LSI 3.1 learning styles the pedagogical implications content-interaction strategy was significantly less preferred than the other four strategies. This may be explained by several factors.

First, the pedagogical implications strategy contained the least amount of content interaction across the seven web modules: its content is comprised of only text and static images (Appendix C). As described by the content-interaction preferences by Anderson (2003), for learning content interaction to be meaningful, it might include virtual labs, videos, animations, simulations, embedded assessments, tutorials, etc., of which the pedagogical implications components in the web-based modules had none. This significant identification of the least favored learner-content interaction strategy seems to support Anderson's Equivalency of Interaction Theory (2003), as all the other interaction strategies were rated significantly more favorable and did include the components espoused by Anderson as highly engaging in self-directed e-learning environments focused on learner-content interactions (Figure 1).

Second, a majority of educators comprising this sample were in grades 3 – 6 (the target sample for the study), and approximately 51% had 10–20+ years teaching experience. The smallest percentage of teachers in this sample had 0–3 years experience (12%), so the pedagogical implications component might have been least desirable because they may not have felt they needed assistance on science teaching strategies given these skills are a primary focus of preservice and early career elementary teachers of science (Berliner, 1986; Hudson, 2004; Jeanpierre, 2007; Mulholland & Wallace, 2005). They may have found the science content knowledge components in the web modules more worthwhile to their needs. This would seem to be supported by the literature where elementary educators have little formal training across the science disciplines they may be asked to teach (Banilower, et al., 2006; Council of Chief State

School Officers, 2007a; Heywood, 2007; Kennedy, 1998). If this is the case, it is unfortunate as many researchers now agree that student achievement is significantly linked to teacher quality as defined by teachers' knowledge and ability to apply subject matter and pedagogical content knowledge related to the subjects they teach (Bransford, et al., 2000; Clermont & Borko, 1994; Darling-Hammond, 2006; Economic Policy Institute, 2003; Goldhaber, 2002; Goldhaber & Brewer, 1998; O. Lee, 1995; Mestre & Cocking, 2002; Monk, 1994; Mundry, 2005; National Center for Research on Teacher Education, 1990; National Commission on Teaching and America's Future, 1996; The Council of Chief State School Officers, 2007; U.S. Department of Education, 2004; Weinburgh, et al., 2008; Whitehurst, 2002; Wilson, et al., 2002).

Pedagogical content knowledge is unique to the field of education as it goes beyond knowledge of subject matter expertise to also include knowledge of how to teach the subject (Shulman, 1986). As Shulman poetically espoused in 1987—and has been demonstrated in aggregated reviews in the novice-expert and education production literature (Bransford, et al., 2000; Clermont & Borko, 1994; Economic Policy Institute, 2003; Haycock, 1998; National Center for Research on Teacher Education, 1990)—deep and flexible understanding of subject matter knowledge is a necessary condition for excellence in teaching, including the elementary level (Feiman-Nemser & Parker, 1990; Luera, 2005; Mulholland & Wallace, 2005), but content knowledge in and of itself is not sufficient (Ball, 1990; Feiman-Nemser & Parker, 1990; Grossman, et al., 1989; Ma, 1999; Shulman, 1987). Pedagogical content knowledge involves the ability of educators to transform and apply deep content knowledge through appropriate and varied instructional strategies, materials, analogies, explanations, examples, and representations, coupled with an intellectual knowledge of how students learn given their cultural predilections and dialectics (Abell, 2007; Gess-Newsome & Lederman, 1999; Ma, 1999).

The pedagogical implications component of the self-directed web modules focus on the appropriate strategies, common misconceptions related to particular science phenomena, and what is cognitively appropriate for students by grade band. Thus, these findings may inform future instructional designers to incorporate richer content-interaction strategies when creating on-demand, self-directed e-PD, possibly including videos of classroom practice for teachers to observe descriptive cases where teachers may ponder strategies to improve student learning or as part of their own self-reflection (Nemirovsky & Galvis, 2004; Rich & Hannafin, 2009). The current pedagogical implications components in the self-directed web modules in this study are very didactic in nature and provide little “cognitive engagement” for educators. While knowledge of learning style preferences as related to different content-interaction strategies in online e-PD are important to instructional designers and administrators, discussion of their development and implementation should also consider their learning efficacy.

Teachers’ learning gains with self-directed web modules. This study also sought to measure the learning impact on teachers completing self-directed web modules and was added at the request of the doctoral committee. While generalization to those beyond this study is limited given nonrandom assignment to treatment and nonrandom sampling from the population, it will provide worthwhile data in the context of an exploratory descriptive study seeking to discern all facets of the phenomenon under examination, and may lend explanatory power when coupled with other research findings. As stated in the results in Chapter 3, teachers’ posttests and final assessment mean scores across the seven science content areas were higher than their respective mean scores on the pretests, and at a level that was significant (Table 17). Thus, on two separate instruments, teachers showed significant growth in learning the science concepts that were addressed in the self-directed web modules. Both of these results were very significant ($p <$

.001): pretest–posttest, $t(101) = 11.63, p < .001$; pretest–final assessment, $t(101) = 10.84, p < .001$.

These findings were predicted given an emerging consensus at the K–12 level in science that simulations and computer-based instruction provide representations and interaction that enhances user motivation and learning (Kulik, 1991; J. Lee, 1999; Linn, et al., 2006; Lunetta, et al., 2007; Songer, 2007; Varma, et al., 2008; Vogel, et al., 2006; Zucker, et al., 2008). In two meta-analysis studies, researchers stated the challenge of potentially confounding variables across studies and suggested caution in generalizing their findings; however, they remained confident in their identified trends (J. Lee, 1999; Vogel, et al., 2006). Positive learning outcomes for teachers and students are also found in the growing body of literature regarding the potential of interactive learning objects at K–8 grade levels (Downing & Holtz, 2008; Kay & Knaack, 2008; Walker, et al., 2008), and in research exploring interoperable systems that aid learning object construction and sharing across diverse learning preferences (Downing & Holtz, 2008; Shute & Zapata-Rivera, 2008; Turker, Gorgun, & Conlan, 2006).

Positive findings aside, any gross generalizations concerning the leaning efficacy of learning objects or self-directed web modules in general should be strictly avoided. Scholars knowledgeable in educational technology and communications are in wide agreement with Clark’s (1983, 1994) arguments and urge researchers and developers to apply an appropriate mix of media, delivery modes, and instructional methods with the aim to enhance the degree of user engagement and learning, avoiding general claims regarding one media type over another (T. Anderson, 2003; Head, et al., 2002; Lockee, et al., 2002; Mentis, 2008). With a discussion of the findings in light of the research for the six hypotheses addressed, a brief summary follows.

Discussion summary. There seems to be significant and positive correlations between age, years teaching experience, and certain types of online content-interaction strategies (i.e., simulations, interactive reference, and personal feedback). Teachers' preferences as determined by the Kolb (1999) LSI 3.1 instrument were not found to statistically correlate with pre-identified content-interaction strategies based on the Experiential Learning Theory (D. A. Kolb, 1984). One content-interaction strategy, pedagogical implications, was least preferred over the other four at a statistically significant level, which is probably the result of the e-print and non-interactive nature of this content-interaction strategy across the seven self-directed science content web modules. Overall this research does seem to lend credence to designing interactions in self-paced learning that move beyond mere text and static images (e.g., e-textbooks) and incorporate cognitively engaging opportunities to interact with the content in dynamic ways (McLoughlin & Lee, 2008b). Finally, teachers had significant gains in knowledge of the science content as measured via a pretest, posttest, and final assessment, which has been found in other studies looking at learning gains in self-directed e-PD. Positive findings aside, some in the science education community warn against simple "minds-off" electronic page turners for professional development (Charles & Griffin, 2007), while others in distressed education communities see web-based self-directed PD as a critical avenue of support not only in countries with struggling economies but as a viable learning option for all educators (Mushayikwa & Lubben, 2009).

Research Implications

Implications for this study will address the following areas: (a) support or lack thereof for Anderson's Equivalency of Interaction Theorem (2003), (b) recommendations for education administrators charged with the selection of science PD for the teachers they serve, and (c)

considerations for instructional designers charged with creating interactive professional development in science.

Implications for Anderson’s Equivalency of Interaction Theorem. The positive, significant learning outcomes from this study across seven different science content areas buttress Anderson’s theory about the learning efficacy possible in self-directed online learning experiences if the content-interaction strategy afforded via the technology is instructionally sound and rich. An “equivalency” effect seems to be achievable for certain types of content-interaction such as simulations, interactive reference, and personal feedback that incorporates feedback strategies to support learning. The learning efficacy found in this study is supported by others, such as Russell et al. (2009), where they too found positive and significant gains for learners who completed self-directed web modules, stating

...findings suggest that when a course is well designed and employs high-quality reading material and learning activities, the high levels of facilitation or interactions among participants may not be necessary to produce positive effects on teachers’ pedagogical beliefs, instructional practices, and, to a lesser extent, understanding of mathematics teaching. (p. 462)

Similar significant and positive learning results were found for 81% of the 43 teachers in grades 4–8 in Krall et al. (2009), who completed self-paced web modules that included email moderator support, as measured via a pretest/posttest content knowledge assessment using paired sample *t*-tests, $t(42, 43) = 8.281, p < .001$. Interestingly, in the Krall et al. study (2009), the interaction of the instructor was rated by participants as the least valuable component of the self-paced web module that included hands-on investigations at a distance. These findings agree with other studies that concluded e-learning modules are a worthwhile and convenient compliment to other

PD efforts, and if designed properly, with high learner-content interactivity, may address a wide continuum of teachers of various ages from preservice to inservice, (Fenton & Watkins, 2007; Sherman, et al., 2008; Walker, et al., 2008; Woodbury, 2008). This notion is also supported by findings in the corporate workplace as well, where tens of thousands of adults are consuming e-learning modules that permit various learner-content interaction strategies to address multiple adult learning preferences (Waight & Stewart, 2005a, 2005b).

Not all learners see the value of online communities (e.g., professional adult learners in graduate school) (Lapointe & Reisetter, 2008), or their need to participate heavily in them (Daugherty, et al., 2005; S. Yoon & R., 2003). This may corroborate with those learners described by del Valle and Duffy (2009) as task focused, with little additional time to engage in dialog that at times may appear superficial (Lapointe & Reisetter, 2008), or is not considered high priority for certain adult learners (Su, et al., 2005; S. Yoon & R., 2003) . With this knowledge, forced online group projects may not be amenable to adult working professionals with little extra time juggling career, family, and professional development (Jiang, et al., 2006; Maor & Volet, 2007). Although, enabling voluntary online cohorts of learners in the same content area has been found to be beneficial (Jiang, et al., 2006), and learners may even self-organize if cohorts are not intentionally structured within the online learning environment (Krall, et al., 2009). Interestingly, while research by Hur and Brush (2009) document the socialization, camaraderie and exchange of ideas as primary reasons for teachers voluntarily participating in online communities, others find educator participation in large communities challenging to sustain (S. Barab, The ILF Design Team, Makinster, Moore, & Cunningham, 2001; Schlager & Fusco, 2003) or start from scratch (Oliver, Herrington, Herrington, & Reeves, 2007).

Collectively, the positive learning outcomes from the research, along with those cited above,

seem to lend credence to Anderson's Equivalency of Interaction Theorem (T. Anderson, 2003) where an effective learning experience may be achieved if the quality of the learner-content interaction is rich. Anderson (2003) says when all three interaction strategies are provided (i.e., learner-learner, learner-content, and learner-instructor), this presents the optimal support paradigm for learners, but he goes on to say, issues of sustainability make this "trifecta" challenging to scale and support for larger pools of learners. With this knowledge in hand, how might it inform administrators charged with the selection and implementation of PD for the teachers they serve?

Implications for administrators. In light of these collective findings concerning the engagement and learning potential of content-interaction strategies that involve simulations, etc., education administrators may seek to provide teachers with a level of autonomy, self-regulation, and self-reflection over their own learning that involves these components as they seek to encourage teachers from extrinsically motivated learning to learning that is internally regulated and intrinsically motivated. There may be utility for education administrators to conduct a learner analysis for the teacher workforce they serve and then select a varied suite of online PD offerings to address a wide set of needs and learning consumption preferences. Given the transitory nature of teachers and their migration between schools, which create a teaching within-field, out-of-field phenomenon (Ingersoll, 1999; U.S. Department of Education, 2004), conducting needs analyses of the teacher workforce may help administrators to better select PD experiences suited for their respective audiences (Waight & Stewart, 2005a). The "one-size-fits-all" approach to PD may leave many educators' unsatisfied (L. Anderson & Olsen, 2006; O'Keeffe, Brady, Conlan, & Wade, 2006), and online options may provide an affordable augmentation to face-to-face experiences (Waight & Stewart, 2005a). For example, dynamic

just-in-time learning objects may provide access to rich archival resources as needed and address teachers' varied learning preferences and diverse pedagogical strategies for learning (Cavanaugh & Dawson, 2010; Dede, et al., 2009; O'Keeffe, et al., 2006; Shimic, 2008). Conversely, the promise of learning objects to accommodate varied learning styles is challenging, but emerging platform and design protocols are attempting to address this in a real and systematic way (Shimic, 2008; Turker, et al., 2006). While teachers and researchers find interactive reference and simulation interaction strategies worthwhile and generally effective for learning and assessment as part of the suite of strategies for online learning (Bayraktar, 2001; Bensen, 2003; J. Lee, 1999; Reed & Jazo, 2002; Schaller, et al., 2007), students' preferences for content-interaction strategies that are less "gamelike" are not always favorably rated (Kay & Knaack, 2008). Thus, some see these strategies along a continuum with overlap between games, simulations, and virtual worlds (Aldrich, 2009). Regardless of these nuances, when administrators are selecting the suite of PD opportunities they will make available to their teachers, considering self-directed online professional development experiences that incorporate the content-interaction strategies found significantly correlated to teacher learning preferences in this study would seem worthwhile and provide a higher impact than digital repositories comprised solely of less interactive digital e-print journal articles or books.

As called for in the 2010 U.S. Department of Education National Technology Education Plan, teachers should be leveraging interactive on-demand web resources that provide real-time feedback about their progress as part of their ongoing professional development. Through online learning systems, teachers may enhance their learning through blending the best of onsite PD with online PD that provides immediacy, convenience, self-direction, and collaboration with other colleagues and experts via professional learning communities (U.S. Department of

Education & Technology, 2010). For teachers to effectively facilitate using interactive resources, learning systems, and connectedness to online communities, teachers need to experience it firsthand as part of their own learning and professional development (U.S. Department of Education & Technology, 2010).

Implications for instructional designers. This body of research also informs instructional designers charged with creating e-learning web modules and learning objects. In support of his Equivalency of Interaction Theorem, Anderson (2003) states common strategies and tools may “include computer assisted learning tutorials, drills, synthesis of content retrieved from the Net and simulations” (p. 9). Anderson claims that while we may place a premium on learner-instructor interaction in online learning, it is not always needed and is challenging to scale on a global level. Anderson (2003) suggests that learner-content interaction may be designed to minimize the amount of learner-instructor interaction needed and still achieve a positive learning outcome for the learner. The findings from this study seem to support this theory. In that regard, [Appendix D](#) presents the instructional strategies and templates employed for the web-based modules used in this study based on an inquiry-based approach to learning (National Research Council, 2000). Given the positive significant teacher learning outcomes reported in this study and that of others finding similar learning outcomes (Chadwick, in press; Sherman, et al., 2008), instructional designers may review these templates to inform future design efforts in self-directed e-PD content and the different types of interaction strategies outlined by these templates ([Appendix D](#)).

These templates, or more specifically, the simulations, animations, slideshows, and audiovisual components of the interactive reference content-interaction strategies were informed by research with respect to Cognitive Theory in Multimedia Learning (CTML) (Mayer &

Moreno, 2003; Moreno & Valdez, 2005; Morrison & Anglin, 2005; van Merriënboer & Ayers, 2005), whereby one seeks to ease the load of information being processed in working memory. The load on working memory may be affected by intrinsic, extraneous, or germane cognitive load and all work in an additive fashion (van Merriënboer & Ayers, 2005). Intrinsic load deals with the nature of the materials and their interaction with the learner based on his or her level of expertise while extraneous cognitive load focuses in part on the multimodalities of information presented (e.g., audio and visual). The goal is to limit extraneous cognitive load, while increasing the availability of mental resources for intrinsic learning. Lastly, germane cognitive load focuses on the processes relevant to learning, such as the construction of conceptual models that may involve motivating the learner to invest in the learning process (Mayer & Moreno, 2003; van Merriënboer & Ayers, 2005). For example, the simulations, animations, and QuickTime Movies that were part of the web modules attempt to appear simple yet elegant and seek to remove superfluous information not relevant to the causal relationship and science concept they are attempting to facilitate (e.g., weeding the content to facilitate a coherence effect). This same notion is applied in the selection of the content itself, applying an “Understanding by Design” approach that seeks to focus on only the enduring understandings and essential learning goals necessary for the outcomes desired (Wiggins & McTighe, 2005).

Following Mayer and Moreno’s (2003) notion of a limited working memory and the assumption of dual channels to process information, the simulations, animations, slideshows, and movies permit the learner to control the pace of the advancing content and in most instances do not present animated text embedded within the visual content. Similarly, “segmenting” and “pretraining” of the self-directed e-PD content is employed, whereby the learners may diagnose or “index” their science content needs, and then select individual “chunks” or learning objects

targeted at those needs (e.g., select individual objects for each of Newton's laws of motion). Within an individual learning object, smaller topics are also presented for the learner (e.g., a learning object on position and motion is further divided into the smaller topics of position, motion, changes in motion, and a "tying it all together" topic followed by final formative quiz at the conclusion of each object). One type of overload, "Aligning and Eliminating Redundancy When the System Is Overloaded by Incidental Processing Demands Attributable to How the Essential Material Is Presented" (p. 48), deals with the load inflicted when images and the related text are not in close proximity to one another (Mayer & Moreno, 2003). In the web modules, this load is reduced by keeping all images, check-your-thinking mouse-overs, and slideshows embedded "in-line" in the text and in close proximity to their respective narrative.

Although, the animations, simulations, and movies in the web modules open in a separate player window, which may be adding unnecessary incidental processing loads labeled in the literature as "split-attention effect" as the learner scans across the screen to take in all the content (Mayer & Moreno, 2003; Sweller, 2004). Conversely, with larger and more affordable monitors, the separate window for this media allow learners to have the multiple-choice questions open and directly parallel alongside the multimedia whereby learners may have a reduced load avoiding the necessity to scroll back and forth between the media and the two or three questions that accompany each animation, simulation, or movie. Interestingly, Mayer and Moreno describe another potential "load" when redundant content is presented for the learner (e.g., audio narration mimicking the text on screen) (2003). The web modules do have this potential load as well where an "audio" button provides a narration option that is nearly identical to the text on screen. That said, I believe the optimal word is *optional* as the learner is not forced to handle both channels simultaneously, but select from the one that they prefer to learn by. Interestingly, focus

groups have revealed the audio narration option as a very favorable component of the web modules.

The personal feedback learner-content interaction strategies in this research dealt largely with the nature of the feedback provided via different types of multiple-choice questions that were meant to cognitively engage the learner as he or she worked through the interactive media, text, and images in the web modules. Instructional designers would be well served to reference the seminal review by Narciss (2008) in applying the most effective feedback structure for questions in future projects. For example, the web modules in this study employed a large variety of feedback types discussed in Narciss (2008) such as “Knowledge of Performance” (p. 132) for summative feedback in the final assessment at the end of each web module. Embedded throughout the web modules and particularly after each animation and simulation or chunk of narrative text and images, learners were presented with questions that provided the following types of feedback: (a) knowledge of result—correctness of response, (b) knowledge of correct response, (c) answer-until-correct opportunities, (d) multiple-try feedback opportunities, and (e) elaborated feedback based on selection made (Narciss, 2008). Within the elaborated feedback researchers agree that the feedback function should serve multiple purposes for the learner, such as: (a) acknowledge and reinforce, (b) inform and guide, (c) instruct, and (d) motivate (Narciss, 2008). While space here limits further explication of this rich body of work, the web module questions provided responses that incorporated many of these functions and structures, which required significant work on the part of the course module designers, assessment experts, and content authors. Given the significant learning outcomes, favorable teacher perceptions, and positive correlations for interactive reference, personal feedback, and simulations content-

interaction strategies, the results of this study may inform instructional designers future e-PD development efforts.

Future Research Implications

There are many potential extensions for research from this study. One might focus on a further refinement of the learner-content interaction strategies defined in this study, seeking additional insight into which areas within a particular strategy support learning effectiveness based on other teacher demographics, learner characteristics, or prior knowledge in different science subject domains and grade levels. One could examine the different levels of incentives and support structures necessary for the effective deployment of self-directed e-PD or blended professional development experiences. There is also a rich area with respect to the dynamic nature of the delivery systems themselves, that are seeking to address different learner preferences and pedagogies within a learning object environment (Turker, et al., 2006) and through self-directed web modules for e-PD (Cavanaugh & Dawson, 2010). While these are potential areas of further exploration, the notion of learner motivation as supported by Ryan and Deci's (2000) Self-Determination Theory discussed in Chapter 2 seems a worthy area of research with respect to self-directed e-PD.

Learner motivation is cited as a key factor to consider when designing learner feedback for self-directed tutoring systems (Narciss, 2008; Shute & Zapata-Rivera, 2008), as well as for simulations within synthetic learning systems (Cannon-Bowers & Bowers, 2008). Perhaps exploring the factors that compel elementary teachers within self-directed online professional development is an area for consideration. One primary concern regarding effective PD (online or otherwise), deals with addressing teachers' beliefs and orientations toward science education, their perceptions regarding their confidence in how to teach science, and their epistemological

and ontological beliefs regarding the nature of science and understanding of science concepts, respectively (Howitt, 2007; Kang, 2007; Pajares, 1992). A large body of research shows that beliefs, attitudes, perceptions, and personal experiences affect part of a larger belief system that is deeply seated, resistant to change, and inconsistent. Ultimately, this belief system affects the pedagogical strategies elementary teachers employ, the content areas they emphasize and are motivated to learn, and the instructional time they allocate to different subjects in their classrooms (Brickhouse, 1990; Horizon Research, 2003; Jones & Carter, 2007; Kang, 2007; C. A. Lee & Houseal, 2003; Morine-Dershimer & Kent, 1999; Munck, 2007; Nespore, 1987; Pajares, 1992; Parker, 2004; Posner, et al., 1982; Schmidt & Buchman, 1983; Simmons, et al., 1999; Tobin & Fraser, 1990; Wenner, 1993; Yerrick, Parke, & Nugent, 1997). How might self-directed e-PD systems explore and expand the learner content-interaction strategies in this research to enhance the intrinsic motivation expressed by Ryan and Deci (2000) that propels certain teachers to excellence despite lackluster online PD opportunities? What types of strategies and analysis can better inform which features of online teacher professional development are more motivational and engaging than others (Dede, et al., 2009)?

Before leaving this idea, it should be noted that on-demand, self-directed e-PD doesn't necessarily mean learning "home alone," reminiscent of correspondence courses years ago. Mentis (2008) provides a realistic portrayal of three self-directed online learning vignettes, with one akin to a very isolated "home alone" experience above. Mentis (2008) then provides an e-Learning Alignment Guide to aid designers as they orchestrate various technologies, pedagogies, and contexts for learning. As web 2.0 technologies begin to empower more self-directed learner control and autonomy (McLoughlin & Lee, 2008a, 2008b), and access to content and learning expands anytime anywhere via mobile technologies (Caudill, 2007; Cobcroft, Towers, Smith, &

Axel, 2006; Ducut & Fontelo, 2009), coupling effective content-interaction strategies, and self-directed engagement with other informal learners becomes a potentially strong mix for self-motivated learning worth further exploration. Tangential to this area of teacher motivation, instructional designers and researchers alike could also explore the theoretical frameworks behind cognitive load theory across several areas with respect to online multimedia-based learning. Researchers are currently exploring how design strategies of CTML may affect learners with different cognitive abilities and prerequisite levels of knowledge (Schnotz & Rasch, 2005), and some suggest we should explore the relationship between motivation and the effectiveness of different instructional formats as related to mental effort exhausted on the part of the learner (van Gog, Ericsson, Rikers, & Paas, 2005). With areas of potential research discussed several closing summary thoughts for education administrators follows.

Personal Reflections

Some have expressed challenges in focusing on learner-content interaction and its lack of discussion in the literature given different content may require different interaction patterns, thus making generalized discussions difficult (Su, et al., 2005). The intent of this study in part was to address this challenge within the area of science education and electronic professional development, as standardized content-interaction strategies are beginning to emerge (i.e., simulations, interactive reference, hands-on activities, pedagogical implications, and personal feedback). The effectiveness of and perceptions for three of these five learner-content interaction strategies were found to significantly and positively correlate with teachers' age and years teaching experience for elementary teachers in grades three – six. Age was positively correlated with the learner-content interaction strategies of simulations, personal feedback, and interactive reference. Years teaching experience was positively correlated with the content-interaction

strategies of personal feedback and interactive reference. Thus when considering environments such as online gaming and immersive environments, research shows younger students are more keenly acclimated to using these emerging technologies (Cobcroft, et al., 2006; Federation of American Scientists, 2006; Green & McNeese, 2007) and care should be taken if deployed for older teacher workforces.

Similarly, teachers, as digital immigrants, may need the following support to effectively use technology-enabled solutions: (a) access to the equipment with stable and adequate internet connectivity, (b) ongoing professional development (e.g., not a one-shot experience), (c) on-site technical aide as problems arise, (d) administrator buy-in, and (e) possible mentoring and modeling of the technology in situ to feel comfortable integrating its use for the classroom (S. A. Barab, Jackson, & Piekarsky, 2006; Buzhardt, Greenwood, Abbott, & Tapia, 2006; Linn, 2006; Overbaugh & Lu, 2008; The Education Arcade & Massachusetts Institute of Technology, 2009; Varma, et al., 2008; S. W. Yoon, 2003). Administrators will be well served to reference the “Diffusion of Innovation” literature by Rogers (2003) that corroborates the implementation suggestions above before they purchase and deploy a web-enabled e-PD system for their district. Diffusion deals with the process and nature of communication that individuals use and share regarding an innovation, whether technical in nature or otherwise. While the research of this study focused on the efficacy and preferences of on-demand e-PD based on different content-interaction strategies in self-directed learning, it is not suggesting that all PD should be delivered in this fashion, nor deployed without forethought regarding its implementation with respect to technology and organizational support on a district or statewide level (K. S. Yoon, et al., 2008). It is submitted as one viable alternative to address the scale needed to reach the 1.9 million of

teachers of science in the United States (Aud, et al., 2010) in a fashion that might be economically sustainable as compared to face-to-face delivery models alone.

Blended learning involves the mix of pedagogical methods in combination with various learning strategies and delivery modes that seek to involve various degrees of technology-mediated solutions to maximize desired learning outcomes (Kim, Bonk, & Oh, 2008; Verkroost, Meijerink, Lintsen, & Veen, 2008). Blending online components with locally delivered onsite opportunities is a mix that if affordable, Anderson's Equivalency of Interaction Theorem supports as a highly effective method. Teachers will and do communicate amongst themselves, and unless administrators understand and facilitate teachers' perceptions regarding the attributes of a new web-enabled e-PD system (i.e., relative advantage, compatibility, complexity, trialability, and observability), administrators may encounter less-than-desired adoption rates of the e-PD system, regardless of the strength of the learner content-interaction strategies it employs. Thus, this research did not focus on, but has implications for, the use of web-enabled technologies for teacher professional development from a "support and implementation" standpoint (Asbell-Clarke & Rowe, 2007; Linn, 2006; Varma, et al., 2008) as states are now beginning to pilot and deploy these types of self-directed web modules with favorable results (Cavanaugh & Dawson, 2010).

With respect to the field of science education and diffusion of innovation, administrators may be well served in selecting self-directed e-PD web modules that embody a mixture of content-interaction strategies that facilitate inquiry-based conceptual understanding, problem solving, and understanding the nature of science and inquiry. The modules should avoid rote "cookbook" procedural methods that typically involve only verification or confirmation of prior findings and low, nonengaging cognitive skills for learning (e.g., simple click-next page-turning

content) (Lunetta, et al., 2007). Administrators would be well advised to secure an e-PD system that helps diagnose and prescribe resources and opportunities that cater to varied learning needs and preferences for educators at various stages of their career development (L. Anderson & Olsen, 2006; Bensen, 2003). Asbell-Clarke and Rowe (2007) in a review of 40 online science courses discuss the benefit of asynchronous communication to support metacognitive reflection in online learning, and also offer the following observation:

Interestingly, the use of other online technologies such as simulations, visualizations, and interactives are relatively absent from these courses...In many face-to-face science teacher professional development courses, hands-on investigation is rampant. It appears to have been replaced by more minds-on work and discussion in these online courses. While the potential of online discussions for knowledge construction is certainly a fascinating area for future research and development, there may be more value added when visualization tools and hands-on activity are integrated with discussions for an even richer learning environment. (p. 117)

This sentiment is also buttressed by Downing and Holtz (2008) who claim "...the vast majority of Web-based science courses fail to take full advantage of these interactive and *push-pull* technologies...In many cases, components/modules of courses are non-interactive and often resemble nothing more than lectures adapted to the basic learning tools of learning management systems." (p. 122)

It would appear we have room for growth with respect to interactivity in online science education professional development and with this research, I hope to aid instructional designers in creating more engaging and powerful learning via self-directed learning objects, as well as inform education administrators who are charged with selecting e-PD systems and content to

support their local and state-based efforts. Taken from headlines of *Education Week* on September 24, 2010, in an article titled “Report: Poor science education impairs U.S. economy,” Dan Vergano cites findings from the updated “Rising Above the Gathering Storm” report chaired by former Lockheed Martin chief Norman Augustine (Augustine, et al., 2010), which found little improvement in U.S. elementary and secondary education and claims that “our nation’s outlook has worsened” since the last Nation At Risk report in 2005. With this as our motivational incentive, we can ill afford to not to seek out improved e-PD content, strategies, and systems for our nations’ teachers.

Appendix A: Kolb Learning Style Inventory Overview

The Kolb Learning Style Inventory (LSI 3.1) (A. Y. Kolb & Kolb, 2005) is an instrument that was initially developed in 1969 and has been psychometrically improved since its initial version, with current technical specifications “designed to adhere to the standards for educational and psychological testing developed by the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education” (A. Y. Kolb & Kolb, 2005, p. 1).

Users’ learning preference is determined by completing a 12-item survey consisting of four rank order “forced-choice” questions generating a 48 item set of questions. Users rank order one of four response options to each item stem that identify the various interval data learning preference subscales: (a) concrete experience (CE), (b) reflective observation (RO), (c) abstract conceptualization (AC), and (d) active experimentation (AE). This tool is copyrighted and not permissible to publish within this dissertation, but one may contact the Hay Group for access (D. A. Kolb, 1999). Upon completion, users are placed into one of four categorical learning preferences, which are (a) diverging, (b) assimilating, (c) converging, and (d) accommodating (Figure 3). This is determined by totaling all response scores aligned for each learning preference subscale (i.e., CE, RO, AC, and AE). Those with a diverging learning preference vary between the concrete experience and reflective observation subscales and prefer to work in groups and receive personalized feedback (A. Y. Kolb & Kolb, 2005). Learners with the assimilating dominant style lean toward reflective observation and abstract conceptualization subscales and prefer to learn via lectures, readings, and analytical models focused on abstract concepts. Converging learning style individuals are those with high scores on the subscales of abstract conceptualization and active experimentation and prefer to learn with simulations and lab

experiments focusing on practical applications of knowledge. Finally, those with predilections for active experimentation and concrete experiences are hypothesized to prefer hands-on learning experiences and prefer affective group work versus logic and technically focused experiences. See Figure 3 for a visual depiction and description of these categories. A combined score from each of the four subscales determines two bipolar dimensions of learning preferences. One bipolar dimension is labeled as concrete experience-abstract conceptualization (e.g., taking in information) and is designated as CE-AC, while the other bipolar dimension is active experimentation-reflective observation (e.g., processing information) and is designated by AE-RO (A. Y. Kolb & Kolb, 2005). The Kolb (2005) Experiential Learning Cycle (Figure 2) postulates that while learners will apply all four factors for learning, individuals will have a preference for either CE-AC or AE-RO. This bipolar preference is determined by subtracting the CE score from the AC score ($AC - CE = CE-AC$) and subtracting the RO score from the AE score ($AE - RO = AE-RO$) (A. Y. Kolb & Kolb, 2005).

Through decades of research and over 650 studies that have used the LSI inventory since its revisions in 1985, 1999, and 2005, the instrument reports an average internal reliability (test-retest) alpha of .81 (range .73 to .88) and internal construct validity for CE, RO, AC, and AE. The latest LSI version 3.1 includes a random scoring format, and a large diverse normative testing group of more than 6977 users. Validity for the LSI has been established for multiple fields, including education since 1990 (A. Y. Kolb & Kolb, 2005). A recent internal validity and reliability study by Kayes (2005) looking at a sample of 221 undergraduate and graduate business students found support for prior internal reliability of the scales, confirming each of the four subscales (i.e., CE, AE, RO, and AC) with high Chronbach α 's ranging from .77 to .82. Kayes's work also supports the Kolb (2005) two bipolar learning preference factors finding

alphas between .77 and .84 respectively, accounting for over 70% of the variance found. Discriminant construct validity examined reliabilities both within and between each subscale, finding high interscale correlations of .76 to .82 for CE, AE, RO, and AC, and between scale correlations ranging from -.18 to -.48, thus supporting empirically distinct constructs for CE, AE, RO, and AC (Kayes, 2005). Interestingly, some researchers have compared the Kolb LSI 3.1 to other inventories finding similar cross-cutting constructs measured for learning preferences (Mentis, 2008).

In another study involving the impact of learning preference and online learning strategies, Johnson (2007) noted the similarities between the different learning style inventories comparing active-reflective learning versus abstract-concrete learning across the Kolb Learning Style Inventory and the Index of Learning Styles (ILS) developed by Felder and Silverman (1988). Johnson's work used the ILS instrument developed initially for college engineering students and found that undergrads who were classified as "active" in their learning style preferred face-to-face study groups and online quizzes versus paper-and-pencil quizzes and those who were more visual than verbal in their learning styles preferred online quizzes rather than online study groups. Johnson's study measured the impact of 43 undergraduate psychology students' learning styles on achievement across two web-based learning conditions (i.e., online quizzes and study groups). Mean achievement score comparisons across the two groups showed no significant difference, but Johnson did find that as achievement increased for the online study group, these learners tended to be more verbal than visual and more reflective versus active in their learning preference (Johnson, 2007). Online quizzes were not related to learning style, but Johnson reported that the importance of learning preferences was "validated by decreased academic achievement under the less-preferred study condition" (Johnson, 2007, p. 630). She

concludes by positing that web-based learning technology may provide a viable mechanism to support learners' preferred style in light of limited resources, overburdened faculty, and large class sizes.

A similar review of the literature that in part compares the LSI and the ILS is reported by Felder and Brent (2005). This study focused on engineering students and the need to provide varied teaching strategies to accommodate different student learning preferences in an effort to facilitate deeper and more engaging learning experiences. Felder et al. (2005) note the caution that some have regarding learning styles and its lack of a strong theoretical basis, but argue that looking at correlations between different learning preferences, course design, and how these preferences impact on student learning would be of great assistance for instructional designers if even from a heuristic perspective. The Kolb LSI 3.1 (2005) was also used in another recent study looking to glean insight into learning preferences on achievement when comparing face-to-face and online learning environments.

In 2008 Brittan-Powell et al. (2008) investigated the role of learning styles on academic course achievement and students' preferences for course selection comparing fully online or traditional on-site courses. While it has been noted earlier in this document that simplistic comparisons of face-to-face and online distance courses are ill-formed in design and should instead focus on the alignment of the instructional attributes of the media, delivery modes, and various instructional methods within the learning environment, this study does lend explanatory insight into learning preferences and substantiates the use of the Kolb LSI 3.1 (2005) as a current research instrument for classifying learning preferences. This study examined 108 undergraduate students from a Historically Black College/University (HBCU), who self-selected enrollment in a psychological assessment course taught by the same instructor, where the only difference was

course delivery method (Brittan-Powell, et al., 2008). Blackboard and online video lectures were delivered to a study sample of primarily women (91%) using identical notes and PowerPoint slides. Both groups were evaluated using the same mid-term exam and final course exam. A causal-comparative/Ex-Post Facto research design surveyed students who volunteered to take the Kolb LSI 3.1 after completing the in-person final exam for extra credit. A 2×4 chi-square test showed no significant differences between students' learning style and their course selection preference (i.e., face-to-face versus online format). To determine whether a student's learning style influenced achievement (course grade) contingent on course delivery format, a 2×4 ANOVA also revealed no significant differences (NSD) for the main effects of course delivery type or Kolb learning style, or interaction between main effects. Researchers conclude that these results "suggest that there is no relationship between students' academic performance and the Kolb learning style, ...[and that] online education is as efficacious as traditional f2f education when viewed from the perspective of student learning styles" (Brittan-Powell, et al., 2008, p. 44). The researchers appear to infer that for all similar courses, learning preferences do not matter or are equally effective regardless of delivery mode. Other researchers take umbrage with these types of online versus onsite course comparisons and argue these studies are typically ill-formed for research analysis and caution should be taken in their explanations of findings (Bernard, et al., 2004; Lockee, et al., 1999; Lockee, Moore, & Burton, 2001; Welsh, Wanberg, Brown, & Simmering, 2003). These conclusions aside, Brittan-Powell et al. (2008) also surmise that a reevaluation of how learning styles are understood is paramount within the nature of online interaction given what is now possible in online learning environments. Given a brief review of current literature using the Kolb LSI 3.1, it seems axiomatic that a deeper review of its underpinning theory is warranted.

The LSI 3.1 is built upon the Experiential Learning Theory (ELT) (D. A. Kolb, 1984), which has the following six propositions:

1. Learning is best accomplished as an iterative process that incorporates feedback to improve the effectiveness of the learning process.
2. Learning is a process that incorporates students' existing beliefs and understandings about a topic permitting them to examine, test, and refine their knowledge.
3. Learning is a process that seeks equilibrium between the conflict and opposing modes of adaptation to the experiential world in which we live, e.g., concrete experience versus abstract conceptualization and reflective observation versus an active experimentation.
4. Learning is a holistic process that involves cognition and the affective (e.g., perceiving, behaving, thinking, feeling).
5. Learning involves interaction between the person and the environment, accommodating new concepts from experiences and assimilating new experiences with prior concepts.
6. Learning involves creating knowledge as a process that builds on constructivist theories whereby social interaction facilitates personal knowledge construction.

ELT posits that knowledge construction is the process of grasping and transforming experiences, whereby grasping (e.g., perception) occurs between the opposing continuums of concrete experiences (CE) or abstract conceptualization (AO), and transforming (e.g., processing) transpires between the opposing continuums of reflective observations (RO) and active experimentation (AE) (A. Y. Kolb & Kolb, 2005; D. A. Kolb, 1984). ELT argues that

learning is a cyclic and constructive process where learners move recursively between experiencing, reflecting, thinking, and acting within the environment and that learners are affected by what is being learned and the situation in which the learning occurs. Concrete “Deweyian” experiences undergird observations and reflections and serve in “Piagetian” fashion to distill and assimilate abstract concepts, which then have implications for action that may be tested and serve as a guide in creating new experiences (A. Y. Kolb & Kolb, 2005). An idealized ELT learning cycle model claims an individual’s learning style and the learning context affect the process of learning itself whereby learners acquire new knowledge through a transformational adaptation and resolution of conflict between concrete experiences, abstract conceptualization, reflective observations, and active experimentation (D. A. Kolb, 1984). Figure 2 shows the learning cycle espoused by the Experiential Learning Theory. Figure 3 depicts the four opposing constructs that Kolb submits learners move between as they solve problems and engage in active experience of learning. Kolb (1984, p. 30) succinctly states that learners

“...must be able to involve themselves fully, openly and without bias in new experiences (CE). They must be able to reflect on and observe their experiences from many perspectives (RO), they must be able to create concepts that integrate their observations into logically sound theories (AC), and they must be able to use these theories to make decisions and solve problems (AE). Yet this ideal is difficult to achieve. How can one be concrete and immediate and still be theoretical? Learning requires abilities that are polar opposites and the learner, as a result, must continually choose which set of learning abilities he or she will bring to bear in any specific learning situation. More specifically there are two primary dimensions to the learning process. The first dimension represents the

concrete experiencing of events at one end and abstract conceptualization at the other. The other dimension has active experimentation at one extreme and reflective observation at the other. Thus, in the process of learning, one moves in varying degrees.”

While Kolb’s learning preference inventory is an outgrowth of their underlying Experiential Learning Theory and has been subjected to significant empirical research with mixed results showing support in favor of and lacking for ELT (A. Y. Kolb & Kolb, 2005), the researchers posit that the purpose of the inventory is twofold: (a) to metacognitively inform learners of their preferences to improve their learning through selecting approaches that are best suited for different situations, and (b) to provide a research tool for investigating ELT and the characteristics of different learning styles. When used to make “discriminate theoretical predictions” to validate the underlying constructs espoused by ELT, it has been “widely accepted as a useful framework for learning-centered educational innovation, including instructional design, curriculum development, and life-long learning” (A. Y. Kolb & Kolb, 2005, p. 8).

Interestingly, Kolb’s (1984) learning cycle is not dissimilar in certain ways to the inquiry learning process espoused by the National Science Education Standards (National Research Council, 1996, 2000) that encourages learning about science concepts through real-world authentic experiences where cognitive dissonance and discrepant events may be used to elicit learners’ existing knowledge and beliefs about the concept in question (Driver, et al., 2000a, 2000b; Glasson & Lalik, 1993; RMC Research Corporation & Center on Instruction, 2008). Eliciting learners’ prior knowledge draws on the collective research of how students learn (Bransford, et al., 2000), which suggest that deeper, active, and long-term conceptual understanding occurs when knowledge is built upon learners’ prior experiences, allowing them

to formulate new ideas through both relevant intellectual hands-on inquiries and minds-on reflection within a larger conceptual framework. The link to learning styles relates to unique differences in learning as individuals work through the ELT learning cycle. Kolb's research with ELT and learning styles (1984, 1999) posits that learning styles are affected by the following: (a) personality type, (b) educational specialization (i.e., formal learning), (c) career choice, and (d) current job and learning tasks. A recent study (Schaller, et al., 2007) used the Kolb LSI 3.1 to analyze if adult learners and children did indeed prefer online web-based informal learning activities that matched their learning preference, also comparing the independent variables of age and gender. The researchers found that learning style and age were major factors in adults' content selection preferences (comparing adults to children, but not within age ranges of adults themselves). Several hypotheses were verified matching content interactivity type with adult learning preference (i.e., interactive reference and puzzle-mystery) (Schaller, et al., 2007). This study built upon this research using similar labeling and chunking of online content-interaction types (e.g., interactive reference, simulation), and expanded to include an analysis of learning achievement and years teaching experience as well.

Appendix B:
Literature for Online Learning and Professional Development

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
<p>Bayraktar. (2001). A meta-analysis of the effectiveness of computer-assisted instruction in science education.</p>	Effectiveness of computer-assisted instruction (CAI)	Secondary and college science education	Student achievement when compared to traditional instruction.	Overall effect size of 0.273 was calculated from 42 studies yielding 108 effect sizes. 70 ES were positive, 38 negative (favoring traditional instruction). 28 of the positive had ES of .05 or greater (moderate to large effects). 42 of the positive ES were small. Results indicate some study characteristics, e.g., student-to-computer ratio, CAI mode, and duration of treatment were significantly related to the effectiveness of CAI.
<p>del Valle and Duffy. (2009). Online learning: Learner characteristics and their approaches to managing learning.</p>	Self-paced, on-demand, instructor support	Elementary, middle, inquiry and technology integration	Satisfaction, completion via click-stream (where go, patterns of activity, and for how long visit). Learner characteristics across profiles, participant perception, age, teacher experience, content knowledge.	Found that experience and goals for learning seem to reflect type of learning experience online, with those with greater teaching experience spending more time online (mastery), those less experienced “task focused,” and some procrastinators, spend least time online (frequency or duration). Even minimalist pass course, but structure may impact learner.

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
<p>Farahani (2003)*. Existence and importance of online interaction.</p>	<p>Moderated online courses</p>	<p>Biology, physics courses undergraduate</p>	<p>Gender, age, online experience, learning preference, importance and availability of interaction (social variants), satisfaction.</p>	<p>No significant relationship between availability and gender, age, online experience or learning preference. No significant relationship between importance and gender, age, online experience or learning preference. Instructors not feel social interaction outside of their communication to students as important.</p>
<p>Harlen and Doubler (2004). Can teachers learn through enquiry on-line? Studying PD in science delivered on-line and on-campus.</p>	<p>Online short course with hands-on</p>	<p>Elementary and middle science and inquiry</p>	<p>Content and pedagogical knowledge, online delivery methods (f2f/online), types of interaction most preferred: hands-on, inquiry, learner-learner discourse, journals to reflect.</p>	<p>Learning through inquiry, conducting investigations and communicating classmates' most important online components. Online learners showed greater understanding science content and perception of ability to teach science (in actuality, little change in f2f or online in actual understanding of inquiry).</p>

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
<p>Hoskins and van Hooff. (2005)*. Motivation and ability: Which students use online learning and what influence does it have on their achievement?</p>	<p>12-week blended (online and onsite) course</p>	<p>Undergraduates</p>	<p>Frequency of use, age, gender, type of online-content components accessed.</p>	<p>Women more likely to engage in online exchanges. Older students more likely to learn for intrinsic reasons. Those frequented online quizzes, more interactions, demonstrated higher achievement.</p>
<p>Jiang et al. (2006). Effectiveness of web-based learning opportunities in a competency-based program.</p>	<p>Self-paced and moderated courses</p>	<p>Graduates</p>	<p>Student-instructor interaction, project-based vs. quiz-based, group work vs. independent study vs. instructor-led learning.</p>	<p>Course satisfaction function of student-instructor interaction. Group work not preferred by working adult learner. Independent study viable, but instructor monitoring, scaffolding needed. Cohorts for peer support valuable not forced group projects. Learner orientation (style) seems to map to support needed.</p>
<p>Krall et al. (2009). Hands-on at a distance: Evaluation of a temperature and heat distance learning course.</p>	<p>Self-paced, email instructor support online courses</p>	<p>Upper elementary middle level teachers (grades 4–8)</p>	<p>Teacher perceptions, pre/post content knowledge, type of interaction-content components most preferred (kit materials for inquiry, lab activities and investigations, interaction btw learner-instructor, CD-ROM, journal).</p>	<p>Teachers showed significant gains in content knowledge in 6 of 9 concepts assessed for course. 88% perceived course improved understanding in science and 95% need for inquiry in classroom. Significant gains in perception of confidence to teach concepts. Learner characteristics might have played role in performance of 8 teachers who showed no gains in learning. Inquiry and kits</p>

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
<p>Lapointe and Reisetter. (2008). Belonging online: Students' perceptions of the value and efficacy of an online learning community.</p>	<p>Online moderated courses</p>	<p>Graduate Students</p>	<p>Quality and importance of online exchanges, interactive dimensions of course, importance of interaction between learner-instructor and learner-learner as compared to traditional classroom settings.</p>	<p>top two types of interaction (hands-on via learner-content), learner-learner interaction next most highly ranked, then CD-ROM, journaling, email exchange with instructor least important, lowest ranked.</p> <p>Online learner-learner interaction not considered necessity by all. Largest value online, flexibility of learning environment. Course satisfaction function of course design, instructor competence, and learning preference (learning via community—or not).</p>

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
<p>Moreno and Valdez. (2005). Cognitive load and learning effects of having students organize pictures and words in multimedia environments: The role of student interactivity and feedback.</p>	Testing learning impact of simulations	Undergraduate Students	Cognitive load and learning effects of dual-code and interactivity—two multimedia methods intended to promote meaningful learning—were examined. Chain of events leading to lightning formation with words and pictures (Group WP), pictures (Group P), or words (Group W). Some presented organized causal chain of events, others given a self-organization task.	Consistent with cognitive theory of multimedia learning, Condition WP highest in instructional efficiency for retention and transfer. However, having students organize multimedia materials was detrimental to transfer. Two follow-up experiments tested hypotheses that the negative effects of interactivity due to students' lack of time control (Exp. 2) and the form of feedback (Exp. 3). Findings showed interactivity was effective when students were asked to evaluate their answers before receiving corrective feedback from the system.
<p>Rhode. (2009). Interaction equivalency in self-paced online learning environments: An exploration of learner preferences.</p>	Self-paced, on-demand, instructor support	Undergraduate courses with adult learners, technology integration	Learner-content, learner-learner, and learner-instructor interaction. Type of components accessed for learner-content.	Learners self-reported engaged most with learner-instructor and learner-content over learner-learner. Ranked learner-learner lower than other two.
<p>Russell et al. (2009).</p>	Self-paced vs. instructor, vs. facilitator vs.	Middle level mathematics	Content and pedagogical knowledge/achievement, teacher perceptions of value	All four levels of support showed significant gains in self-reported change in pedagogical beliefs and increase in content knowledge.

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
Comparing self-paced and cohort-based online courses for teachers.	peer-peer support models		of different support modes, high scaffolding (learner-instructor, learner-learner, learner-facilitator versus no support, e.g., learner-content.	NSD found between groups based on varied support levels.
Schaller et al. (2002). How do you like to learn? Comparing user preferences and visit length of educational web sites.	Self-paced, on-demand web modules	Informal science (adults/children)	How people's preferences vary among types of web-based learning content (creative play, guided tour, interactive reference, puzzle/interactive mystery, role-playing, simulation). Compare adults versus children preferences.	Adults prefer simulation and interactive reference over role-play and creative play (interaction types for web-based content). Gender showed NSD between control and treatment sites. Implications for design of web-based learning (audience, expertise in domain, types of pedagogical approaches employed). Role-playing site finished more often than expected. Adults less affective, more straight cognitive information.
Schaller et al. (2007). One size does not fit all: Learning style, play, and on-line interactives.	Self-paced, on-demand web modules	Informal science (adults)	Learning style, age, gender on user preferences (Kolb's inventory) for different types of online learning activities.	Learning style does influence individual preferences for learning among adults. Social learners prefer role play, intellectual prefer interactive reference style. Age also is more of a factor than gender. Females are more social than males. Didn't break out specific age groups.
Sherman et al.	On-demand	Middle school	Content knowledge, learner	Significant gains in learning for on-demand

**Online Self-Paced Learning
Research Studies**

Authors and Areas of Research	Program Delivery Model	Target Audience/ Content Area	Variables Examined	Research Findings
(2008). Evaluation of online science PD w/ two implementation models	learning Objects with e-mentor and simulations	science and inquiry	self-efficacy, learner-content interaction.	self-paced groups, self-efficacy gains across all three groups. Simulations found worthwhile, engaging.
Su et al. (2005). The importance of interaction in web-based education: A Program-level case study of online MBA courses.	Moderated instructor-led courses	Online MBA graduate courses	Learner-content, learner-learner, and learner-instructor interaction, types of resources used online, instructor perceptions, learner preferences, demographic-adult learner (gender).	Students vary in regard to level of learner-learner, learner-instructor interaction. Appear related to learning preferences. Instructor-learner interaction key part of program. Males have significantly more positive attitude toward technology ability to facilitate learning than females. Reduced expectations for course interaction for adults with family and job responsibilities.
Whitaker et al. (2007). Use and evaluation of web-based professional development services across participant levels of support.	Self-paced PD	Early childhood support, online PD	Level of participation based on varying levels of support (web limited-voluntary, full web plus print materials, videos, consultancy, all materials, full web plus web conferencing, feedback on user videos), and level of satisfaction. Look at web server logs, teacher evaluation surveys, focus groups.	Group with consultancy logged significantly more hours than other two support groups. Level of support received affects level of participation. Teachers will spend more time in PD if perceived as useful.

Appendix C: Examples of Learner-Content Interaction Strategies

Simulation:

Employs high level of user control, where learners may change the parameters or values of variables within the simulation and see the resultant difference in observed phenomenon (e.g., height of object dropped, type of surface ball is rolling across, etc.). Appears within the SciPack content labeled as "click here to start interactive." In certain instances the "interactive" is more an animation that is viewed with the intent for observation of phenomenon for the science concept in question.

Simulation Example 1 (Force and Motion):

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C5501050000036&courseID=00065BF1B6260A8F2C73...

NSTA
SCIPACKS

Force and Motion
Newton's Second Law

2 OF 7

Home Ask the Wizard Reset Page Previous Next

Net Forces can Cause Change in Direction, Too

Click on the following icon to view a simulation that you already saw when investigating Newton's first law.

Figure 2.7. Applying Force to a Moving Object Simulation
For those unable to engage with the interactive component, select this link for a long text description:
[Text Description](#)

Small change in direction — small acceleration

Large change in direction — large acceleration

What this shows is that net forces can change not only speed but also direction. A drastic change in direction implies a large acceleration and a large applied force, and a small change in direction implies a small acceleration and a small applied force.

NSTA SCIENCE SIMULATION: Applying Force to a Moving Object

INSTRUCTIONS

Before You Begin

Applying Force to a Moving Object provides a controlled opportunity to apply a consistent force in a consistent manner to an object that is in motion or stopped. Play with this simulation by changing the Force Value and the direction of the force applied to see the effect on the sphere. After some practice try to maneuver the sphere in a specific manner to a specific location on the screen.

Use the instructions tab to reveal the specific instructions to operate this interactive simulation.

PROCEED

CONTROL PANEL

TURN TRAILS OFF

Force value = 0

Apply a Force (push) in a direction

BALL DATA - SPEED

X = 5 m/s

Y = 0 m/s

NSTA SCIENCE SIMULATION: Applying Force to a Moving Object

INSTRUCTIONS



CONTROL PANEL

TURN TRAILS OFF

Force value = 5

Apply a Force (push) in a direction

BALL DATA - SPEED

X = 2 m/s

Y = 0 m/s

NSTA SCIENCE SIMULATION: Applying Force to a Moving Object

INSTRUCTIONS

CONTROL PANEL

TURN TRAILS OFF

Force value = 1

Apply a Force (push) in a direction

BALL DATA - SPEED

X = 5 m/s
Y = -2 m/s

NSTA SCIENCE SIMULATION: Applying Force to a Moving Object

INSTRUCTIONS

CONTROL PANEL

TURN TRAILS OFF

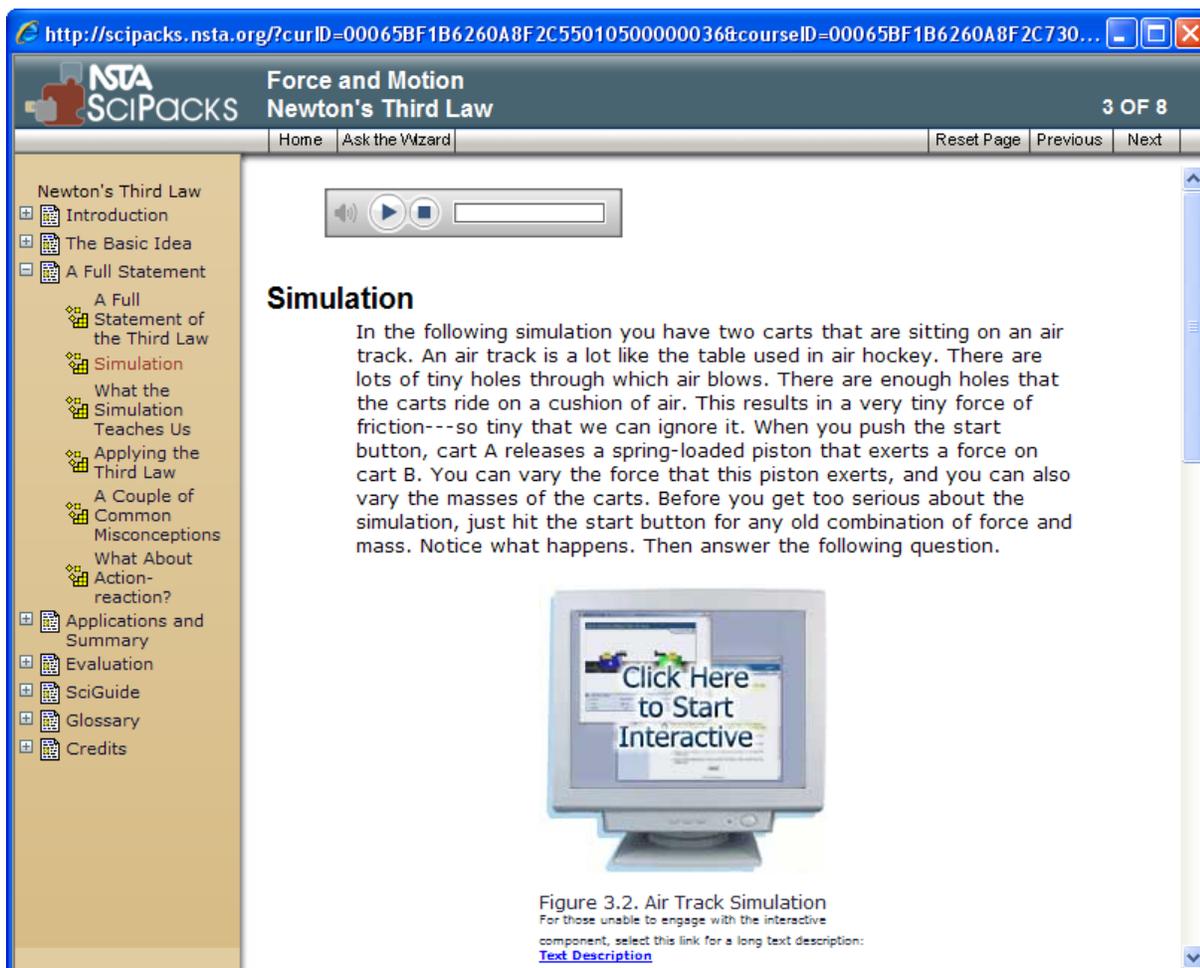
Force value = 3

Apply a Force (push) in a direction

BALL DATA - SPEED

X = 5 m/s
Y = -5 m/s

Simulation Example 2 (Newton's Third Law):



The screenshot shows a web browser window with the URL <http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C5501050000036&courseID=00065BF1B6260A8F2C730...>. The page title is "Force and Motion Newton's Third Law" and it is page "3 OF 8". The left sidebar contains a navigation menu for "Newton's Third Law" with items: Introduction, The Basic Idea, A Full Statement, A Full Statement of the Third Law, Simulation (highlighted), What the Simulation Teaches Us, Applying the Third Law, A Couple of Common Misconceptions, What About Action-reaction?, Applications and Summary, Evaluation, SciGuide, Glossary, and Credits. The main content area features a "Simulation" section with a paragraph of text and a "Click Here to Start Interactive" button. Below the text is an image of a computer monitor displaying the simulation interface. A caption below the image reads: "Figure 3.2. Air Track Simulation For those unable to engage with the interactive component, select this link for a long text description: [Text Description](#)".

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C5501050000036&courseID=00065BF1B6260A8F2C730...

NSTA SciPacks Force and Motion Newton's Third Law 3 OF 8

Home Ask the Wizard Reset Page Previous Next

Newton's Third Law

- Introduction
- The Basic Idea
- A Full Statement
 - A Full Statement of the Third Law
 - Simulation**
 - What the Simulation Teaches Us
 - Applying the Third Law
 - A Couple of Common Misconceptions
 - What About Action-reaction?
- Applications and Summary
- Evaluation
- SciGuide
- Glossary
- Credits

Simulation

In the following simulation you have two carts that are sitting on an air track. An air track is a lot like the table used in air hockey. There are lots of tiny holes through which air blows. There are enough holes that the carts ride on a cushion of air. This results in a very tiny force of friction---so tiny that we can ignore it. When you push the start button, cart A releases a spring-loaded piston that exerts a force on cart B. You can vary the force that this piston exerts, and you can also vary the masses of the carts. Before you get too serious about the simulation, just hit the start button for any old combination of force and mass. Notice what happens. Then answer the following question.



Figure 3.2. Air Track Simulation
For those unable to engage with the interactive component, select this link for a long text description: [Text Description](#)

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

Before You Begin

Air Track is a simulation of an actual piece of physical science lab equipment. Here you are presented with two carts and a limited number of choices, the mass of each cart and the force applied from cart A to cart B. Select one choice for each and run the experiment multiple times. You may use the magnification tool to see more or less of the whole air track.

Use the instructions tab to reveal the specific instructions to operate this interactive simulation.

CONTROL PANEL

PROCEED

	Piston Force	Cart A Mass	Cart B Mass
<input checked="" type="checkbox"/> START	X 1 N	X 1 kg	X 1 kg
<input type="checkbox"/> STOP			
<input type="checkbox"/> RESET	2 N	2 kg	2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

air track magnifier 61 %

CONTROL PANEL

	Piston Force	Cart A Mass	Cart B Mass
<input type="checkbox"/> START			
<input checked="" type="checkbox"/> STOP	X 1 N	X 1 kg	X 1 kg
<input type="checkbox"/> RESET	2 N	2 kg	2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

CONTROL PANEL

	Piston Force	Cart A Mass	Cart B Mass
<input type="checkbox"/> START	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> STOP	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg
<input type="checkbox"/> RESET			

air track magnifier 171 %

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

CONTROL PANEL

	Piston Force	Cart A Mass	Cart B Mass
<input checked="" type="checkbox"/> START	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> STOP	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg
<input type="checkbox"/> RESET			

air track magnifier 171 %

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

air track magnifier 48 %

CONTROL PANEL

<input checked="" type="checkbox"/> START	Piston Force	Cart A Mass	Cart B Mass
<input type="checkbox"/> STOP	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> RESET	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

air track magnifier 48 %

CONTROL PANEL

<input type="checkbox"/> START	Piston Force	Cart A Mass	Cart B Mass
<input checked="" type="checkbox"/> STOP	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> RESET	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

1 kg

A B

-20 -10 -5 0 cm 5 10 20

air track magnifier 89 %

CONTROL PANEL

START STOP RESET

Piston Force

1 N 2 N

Cart A Mass

1 kg 2 kg

Cart B Mass

1 kg 2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

1 kg

A B

-20 -10 -5 0 cm 5 10

air track magnifier 126 %

CONTROL PANEL

START STOP RESET

Piston Force

1 N 2 N

Cart A Mass

1 kg 2 kg

Cart B Mass

1 kg 2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

1 kg

A

B

air track magnifier 89 %

CONTROL PANEL

	Piston Force	Cart A Mass	Cart B Mass
<input type="checkbox"/> START	<input checked="" type="checkbox"/> 1 N	<input type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input checked="" type="checkbox"/> STOP	<input type="checkbox"/> 2 N	<input checked="" type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg
<input type="checkbox"/> RESET			

Simulation Example 3 (Plate Tectonics):

The screenshot shows a web browser window with the URL <http://scipacks.nsta.org/?curID=00065BF1B6260BB3CA4A010500000052&courseID=00065BF1B6260BB3CB6C...>. The page header includes the NSTA SciPacks logo and the title "Plate Tectonics Layered Earth". A navigation bar contains "Home", "Ask the Wizard", "Reset Page", "Previous", and "Next". A sidebar on the left lists various topics under "Layered Earth", including "Earth Changing Events", "Defining Principles", "Observing Principles", "Wave Behavior", "Seismic Waves", "Seismic Waves and Layers", "Tremors Revisited", "Revealing Properties", "Layer by Layer", "Evaluate", "Glossary", and "Credits".

The main content area features a "Seismic Waves" section with the following text:

Seismic Waves

Before embarking on the great scientific quest to explore beneath the surface of the Earth, perhaps it would be best to use a simulation to breathe life into the three principles that define seismic wave behavior. Experiment with the layers of different properties and pay attention to how the waves refract or bend based on the characteristics of those layers.

Below the text is an image of a computer monitor displaying a simulation interface with the text "Click Here to Start Interactive".

Figure 3.2. Seismic Waves animation
For those unable to engage with the interactive component, select this link for a long text description:
[Text Description](#)

At the bottom of the main content area, there is another paragraph of text:

Notice how the waves bend or refract when the layers are different, but travel along a straight path when the layers are of the same density or rigidity? Can you tell which waves are traveling faster—the waves in the less-dense layer or the waves in the more-dense layer? The waves in the less-rigid layer or the waves in the more-rigid layer? Be sure to examine the velocity graph along the right side of the simulation before proceeding, because the velocity of seismic waves reveals much about the interior of the Earth.

NSTA SCIENCE SIMULATION: *Seismic Waves*

INSTRUCTIONS

Before You Begin

In this simulation, you may choose layers according to density or rigidity. When you press the "start" button you are triggering a seismic event. Observe how the velocity and direction of the seismic waves change based on the properties of the layers.

VELOCITY

CONTROL PANEL

PROCEED → FAST

START STOP RESET

TEST FOR: Rigidity Density

Top Layer High Low

Bottom Layer High Low

NSTA SCIENCE SIMULATION: *Seismic Waves*

INSTRUCTIONS

VELOCITY

DEPTH

RIGIDITY: HIGH

RIGIDITY: LOW

SLOW → FAST

CONTROL PANEL

START STOP RESET

TEST FOR: Rigidity Density

Top Layer High Low

Bottom Layer High Low

NSTA SCIENCE SIMULATION: Seismic Waves

INSTRUCTIONS



VELOCITY

DEPTH

SLOW → FAST

CONTROL PANEL

START

STOP

RESET

TEST FOR:

Rigidity

Density

Top Layer

High

Low

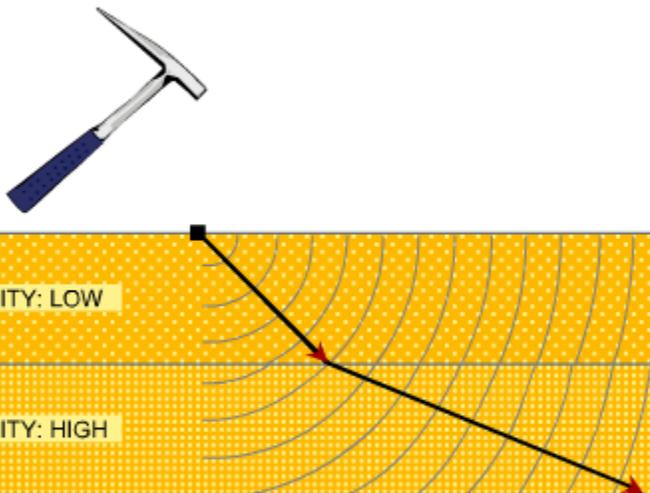
Bottom Layer

High

Low

NSTA SCIENCE SIMULATION: Seismic Waves

INSTRUCTIONS



VELOCITY

DEPTH

SLOW → FAST

CONTROL PANEL

START

STOP

RESET

TEST FOR:

Rigidity

Density

Top Layer

High

Low

Bottom Layer

High

Low

Hands-On Activity:

Description of tangible activity adult learner may engage with at home to help understand the science concept or phenomenon under examination. Typically includes brief description of procedure, and materials that are readily accessible (not complex science chemicals or apparatus). Appears several times throughout the SciPack as a stand-alone box, with a pop-up window or the activity.

Hands-On Activity Example 1 (Force and Motion):



Hands-On Activity

Instead of watching a virtual ball roll across a smooth surface, you can actually do it. Grab a small ball or marble and find a smooth, flat surface such as a table top or a bare floor. Then click on the link to go to the activity:

[Hands-On Activity](#)

<http://scipacks.nsta.org/?contentID=00065BF1B6260A9DB6CC01010000D97&docM...>

Hands-On Activity

Get a ruler or a meterstick and measure off a distance of about 1 meter. The actual distance isn't important, but the numbers we'll use later will assume you measured 1 meter. Mark the beginning and end of this distance with masking tape. What you're going to do is time how long it takes for the ball to roll this distance. To do this, start rolling the ball before the first mark, start timing when it reaches the first mark, and stop timing when the ball reaches the second mark.

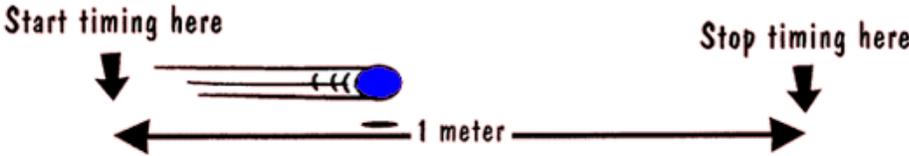


Figure 3.3

For timing purposes, a stopwatch would be nice but is not necessary. A clock or watch with a second hand will do, or just counting (one one thousand, two one thousand, ...) works just fine. Accuracy isn't all that important here.

Once you're all set, go for it. Time a few runs and record the times in the table below. If you're not using a stopwatch, try to guess at half seconds. If you come up with times that are less than one tenth of a second or more than 4 seconds, you're doing something unusual. Check your numbers to make sure that rolling the ball faster results in shorter times and rolling the ball slower results in longer times.

Copyright NSTA 2007

Hands-On Activity Example 2 (Force and Motion):



Hands-On Activity

You can try something like this on your own. Select the following link to find out how: [Hands-On Activity](#)

<http://scipacks.nsta.org/?contentID=00065BF1B6260B8F18630101000013AA&docMo...>

Hands-On Activity

Chances are you don't have any space ships lying around the house, but you can do something that will give you a result that's similar to what you have observed in the simulation. Get two Ping-Pong balls and set them on a smooth surface. Hit one of them with a large force and one with a small force. What difference do you notice in the resultant change in motion of the balls? You should get something similar to what happened with the identical space ships that experienced different thrusts.

Now grab a golf ball and set it next to the Ping-Pong ball on a smooth surface. See if you can get them to change their motion (speed up) in almost the same way by hitting the golf ball harder than you hit the Ping-Pong ball. Of course, you could also hit them with about the same force and see what happens.

A photograph showing two white ping-pong balls and one white golf ball on a dark surface. A wooden ruler is placed diagonally in the foreground for scale. The ping-pong balls are positioned at approximately 10 cm and 20 cm on the ruler, while the golf ball is at approximately 15 cm.

Close Window

Copyright NSTA 2007

Hands-on Activity Example 3:



Hands-On Activity

You can do this simulation in real life. All you need is a section of Hot Wheels® track, a marble or ball bearing, a ruler, and a friend to help. Then select the link to go to the Activity:
[Hands-On Activity](#)

Hands-On Activity

Grab a ruler or meterstick, a marble or a ball bearing, and about a meter-long section of Hot Wheels® track. If you don't have access to kids' toys, just use anything you can find that's flexible and will allow a marble to roll along it. What works well is a section of clear plastic tubing (try the hardware or plumbing supply store) and a ball bearing that's small enough to roll freely inside the tubing.

Find a friend or family member to help you with this next part. Hold the track in a U shape so the lowest part just touches a table top or a floor, as seen in Figure 3.10.



Figure 3.10

Now measure the vertical distance from the floor or table to one end of the track. For the directionally challenged, that vertical distance is shown in Figure 3.11.

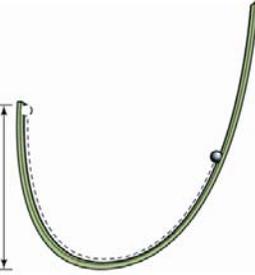


Figure 3.11

If your memory isn't great, write this distance down. You'll need to keep this one side of the track at that same vertical distance as you do the next few things. With your accomplice helping you, hold the track in a U shape with the bottom of the U touching the table or floor; holding your end at the vertical distance you've measured, drop the marble at the top of that end of the track.

Watch what the marble does. It should roll back and forth for a while and finally come to rest. Now do this a few more times, but notice where the marble stops the first time before it goes back in the other direction. When you've done it enough times that the marble seems to stop in just about the same place each time, measure the vertical distance from the table or floor to this point on the track (Figure 3.12).

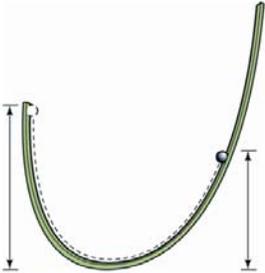


Figure 3.12

Now that you're good at this procedure, you get to repeat it. Only this time change the shape of the track so the second side of the U is lowered a bit (Figure 3.13). As you repeat things, make sure your starting height is the same as it was the first time you did it.

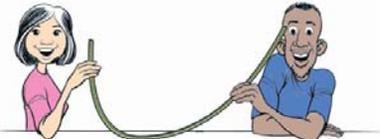


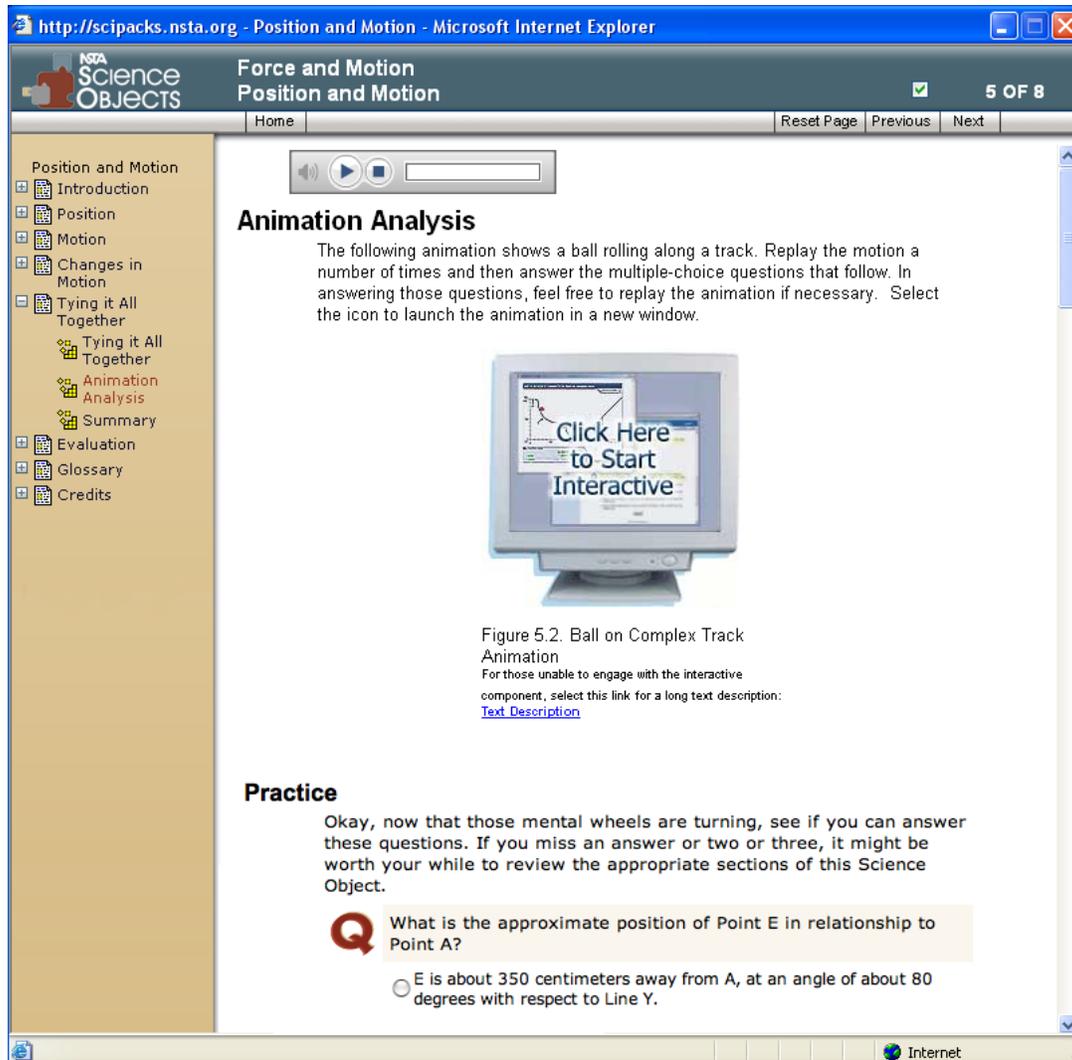
Figure 3.13

Now lower the second side of the U even more and repeat.

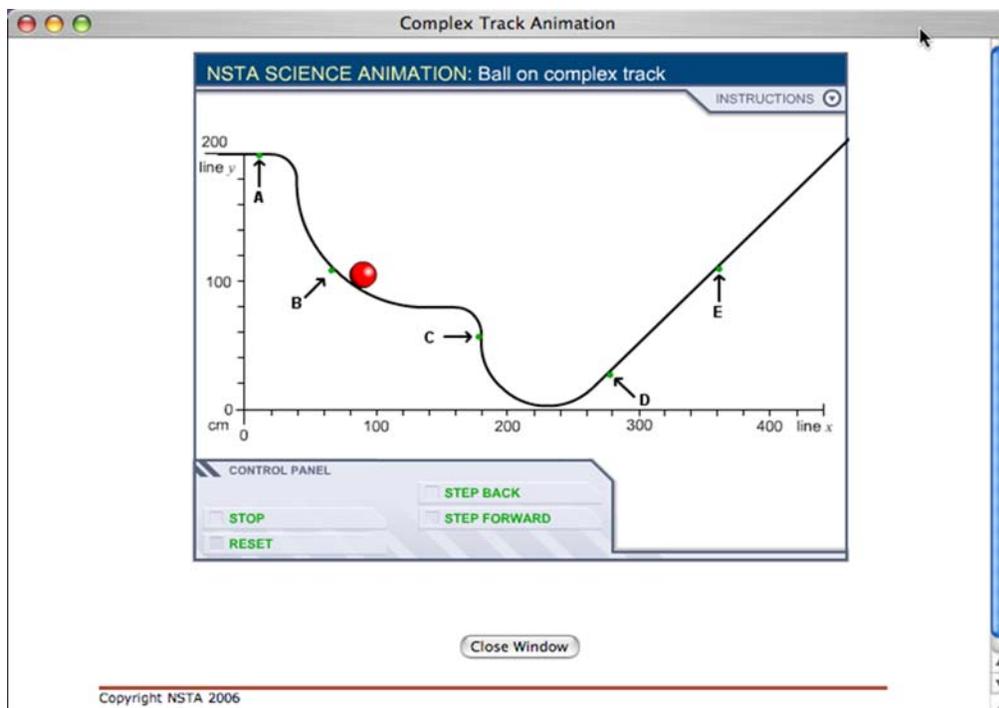
Personal Feedback:

Embedded questions both throughout the content, and a formative quiz at the end of each Science Object. Questions may be multiple-choice single or multiple answer and involve interactivity such as drag and drop, hotspot identification, or sequencing of items in question. Users are provided with rich descriptive feedback after each distractor if selected. Questions contain hints and unique feedback based on challenge learners may be struggling with and in certain instances provide recommendations and URL links to re-review certain content or view new content if the user exhausts the number of attempts for the question and fails to get the correct answer.

Personal Feedback Example 1 (Force and Motion Embedded Questions):



The screenshot shows a web browser window with the address bar displaying "http://scipacks.nsta.org - Position and Motion - Microsoft Internet Explorer". The page title is "Force and Motion Position and Motion" and it is the "5 OF 8" objects in a series. A navigation bar includes "Home", "Reset Page", "Previous", and "Next" buttons. A sidebar on the left lists the following sections: "Position and Motion", "Introduction", "Position", "Motion", "Changes in Motion", "Trying it All Together", "Trying it All Together" (with sub-items "Animation Analysis" and "Summary"), "Evaluation", "Glossary", and "Credits". The main content area features a "Position and Motion" audio player at the top. Below it is the section "Animation Analysis" with the text: "The following animation shows a ball rolling along a track. Replay the motion a number of times and then answer the multiple-choice questions that follow. In answering those questions, feel free to replay the animation if necessary. Select the icon to launch the animation in a new window." An image of a computer monitor displays a graph and the text "Click Here to Start Interactive". Below the image is the caption: "Figure 5.2. Ball on Complex Track Animation" and a link for "Text Description". The "Practice" section follows, with the text: "Okay, now that those mental wheels are turning, see if you can answer these questions. If you miss an answer or two or three, it might be worth your while to review the appropriate sections of this Science Object." A question icon is followed by the text: "What is the approximate position of Point E in relationship to Point A?" and a multiple-choice option: "E is about 350 centimeters away from A, at an angle of about 80 degrees with respect to Line Y."



http://scipacks.nsta.org - Position and Motion - Microsoft Internet Explorer

NSTA Science OBJECTS

Force and Motion
Position and Motion

5 OF 8

Home Reset Page Previous Next

Position and Motion

- Introduction
- Position
- Motion
- Changes in Motion
- Tying it All Together
 - Tying it All Together
 - Animation Analysis

Q The ball has zero acceleration at ...

- Point E, because the ball is at rest at that point.
- Point B, because the direction is constant there.
- Point D, because it's slowing down at that point. It is decelerating but not accelerating.
- Point A, because neither its speed nor its direction are changing there.

Check

points is the instantaneous speed of the ball the

D. The ball is moving fastest at those Points. and depends only on the magnitude of the velocity, and

it is changing its speed the fastest at that point.

the speed has to be largest at the beginning in order for the path.

the ball is slowing down at Point D, it can't have a zero.

Check

Answer Feedback

Please try again.

- Both direction and speed must be unchanging for the acceleration to equal zero.

Close

Done Internet Internet

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C550105000000368&courseID=00065BF1B6260A8F2C73...

NSTA SciPacks Force and Motion Position and Motion 5 OF 9

Home Ask the Wizard Reset Page Previous Next

Position and Motion

- Introduction
- Position
- Motion
- Changes in Motion
- Tying it All Together
 - Tying it All Together
 - Animation Analysis
 - Summary
- Evaluation
- SciGuide
- Glossary
- Credits

Tries Remaining: 3

Q The ball has zero acceleration at ...

- Point A, because neither its speed nor its direction are changing there.
- Point B, because the direction is constant there.
- Point E, because the ball is at rest at that point.
- Point D, because it's slowing down at that point. It is decelerating but not accelerating.

X

Check

Answer Feedback

Please try again.

If the ball is slowing down, that's a change in velocity, meaning a change in direction. Remember that there is no such thing as deceleration in science.

[Close](#)

Selected points is the instantaneous speed of the

use the speed has to be largest at the or it to traverse the entire path.

and D. The ball is moving fastest at those us speed depends only on the magnitude of the e direction.

use the ball is slowing down at Point D, it can't eed there.

use it is changing its speed the fastest at that

Check

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C55010500000036&courseID=00065BF1B6260A8F2C73...

NSTA SciPacks Force and Motion Position and Motion 5 OF 9

Home Ask the Wizard Reset Page Previous Next

Position and Motion

- Introduction
- Position
- Motion
- Changes in Motion
- Tying it All Together
 - Tying it All Together
 - Animation Analysis
 - Summary
- Evaluation
- SciGuide
- Glossary
- Credits

Tries Remaining: 3

Q The ball has zero acceleration at ...

- Point A, because neither its speed nor its direction are changing there.
- Point B, because the direction is constant there.
- Point E, because the ball is at rest at that point.
- Point D, because it's slowing down at that point. It is decelerating but not accelerating.

Check

Answer Feedback

Please try again.

If the ball is at rest, that means the instantaneous velocity is zero. Acceleration, however, is measured by changes in velocity. An object at rest does not necessarily have zero change in velocity.

Close

Selected points is the instantaneous speed of the

use the speed has to be largest at the or it to traverse the entire path.

and D. The ball is moving fastest at those us speed depends only on the magnitude of the direction.

use the ball is slowing down at Point D, it can't eed there.

use it is changing its speed the fastest at that

Check

The screenshot shows a web browser window with the URL `http://scipacks.nsta.org - Position and Motion - Microsoft Internet Explorer`. The page title is "Force and Motion Position and Motion" and it is page "5 OF 8". The main content area displays a question: "The ball has zero acceleration at ...". There are four radio button options:

- Point E, because the ball is at rest at that point.
- Point B, because the direction is constant there.
- Point D, because it's slowing down at that point. It is decelerating but not accelerating.
- Point A, because neither its speed nor its direction are changing there.

 A "Check" button is visible below the options. A feedback window is open in the foreground with the title "Answer Feedback". It contains the text:

Incorrect!

If the ball is at rest, that means the instantaneous velocity is zero. Acceleration, however, is measured by changes in velocity. An object at rest does not necessarily have zero change in velocity.

For more information:

- For help revisit the [One More Definition section](#).
- To see how this information relates to each position in the

 The browser's status bar at the bottom shows "Done" and "Internet".

Once learners exhaust the number of allotted tries for a question in addition to the personalized feedback, they are presented with the correct answer (i.e., Point A above), and in certain instances presented with opportunities to revisit the content again, or view new content to assist in their understanding.

Personal Feedback Example 2 (Force and Motion formative quiz at the end of a Science Object on Position and Motion):

The screenshot shows a web browser window displaying an educational page from NSTA SciPacks. The page title is "Force and Motion Position and Motion" and it is page 6 of 9. A navigation menu includes "Home", "Ask the Wizard", "Reset Page", "Previous", and "Next". A sidebar on the left lists various topics under "Position and Motion", including "Introduction", "Position", "Motion", "Changes in Motion", "Trying it All Together", "Evaluation", "Quiz", "SciGuide", "Glossary", and "Credits".

The main content area is titled "Evaluation" and contains a text block: "This section gives you one more chance to demonstrate your understanding. As with the previous section, these will be new situations in which you can apply your knowledge. Of course, we won't leave you hanging if you don't get the correct answers. It's all about learning, right? In that spirit, we'll not only tell you what answers are right and wrong but also *why* they're right or wrong."

Below this text is a "Quiz" section with a note icon and the text: "How well do you understand Position and Motion? Answer the following questions to find out." The quiz image shows two cars, A and B, on a curved track. Car A is on a sharp curve, and Car B is on a gradual curve.

The caption for the image is "Figure 6.1".

The quiz question is: "Two cars are rounding curves. Both cars are traveling at a constant speed of 40 kilometers per hour. Car A is rounding a very sharp curve and car B is rounding a gradual curve. Which of the following are true regarding the motion of the cars?"

The options are:

- Cars A and B both have zero acceleration because their speeds are not changing.
- Car A and car B have the same acceleration because they have the same speed.
- Car A is accelerating more than car B because it is changing direction at a faster rate.
- Car A and car B have the same acceleration because they have the same velocity.

A "Check" button is located below the options.

An "Answer Feedback" window is open in the bottom right corner, displaying the message: "Please try again. Even if cars A and B have the same velocity at some point, the value of the velocity is not important. Acceleration depends on the change in velocity, not the current value of the velocity." A "Close" button is at the bottom of the feedback window.

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Evaluation

This section gives you one more chance to demonstrate your understanding. As with the previous section, these will be new situations in which you can apply your knowledge. Of course, we won't leave you hanging if you don't get the correct answers. It's all about learning, right? In that spirit, we'll not only tell you what answers are right and wrong but also *why* they're right or wrong.

 **Quiz**

How well do you understand Position and Motion? Answer the following questions to find out.

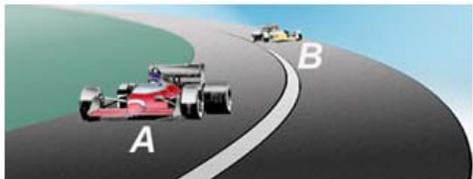


Figure 6.1

Q Two cars are rounding curves. Both cars are traveling at a constant speed of 40 kilometers per hour. Car A is rounding a very sharp curve and car B is rounding a gradual curve. Which of the following are true regarding the motion of the cars?

- Car A is accelerating more than car B because it is changing direction at a faster rate.
- Car A and car B have the same acceleration because they have the same speed.
- Car A and car B have the same acceleration because they have the same velocity.
- Cars A and B both have zero acceleration because their speeds are not changing.

http://scipacks.nsta.org/?curID=00065BF1B62...

Answer Feedback

Please try again.

- Remember that acceleration is defined as a change in speed, direction or both. Both cars are changing direction.

[Close](#)

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Quiz

How well do you understand Position and Motion? Answer the following questions to find out.



Figure 6.1

Q Two cars are rounding curves. Both cars are traveling at a constant speed of 40 kilometers per hour. Car A is rounding a very sharp curve and car B is rounding a gradual curve. Which of the following are true regarding the motion of the cars?

- Cars A and B both have zero acceleration because their speeds are not changing.
- Car A and car B have the same acceleration because they have the same speed.
- Car A is accelerating more than car B because it is changing direction at a faster rate.
- Car A and car B have the same acceleration because they have the same velocity.

http://scipacks.nsta.org/?curID=00065BF1B62...

Answer Feedback

Please try again.

Acceleration is defined as a change in velocity, and velocity involves both speed and direction. If the direction changes, then the object is accelerating. A faster change in direction means a larger acceleration.

[Close](#)

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C550105000000368&courseID=00065BF1B6260A8F2C730...

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This section gives you one more chance to demonstrate your understanding. As with the previous section, these will be new situations in which you can apply your knowledge. Of course, we won't leave you hanging if you don't get the correct answers. It's all about learning, right? In that spirit, we'll not only tell you what answers are right and wrong but also *why* they're right or wrong.

 **Quiz**

How well do you understand Position and Motion? Answer the following questions to find out.

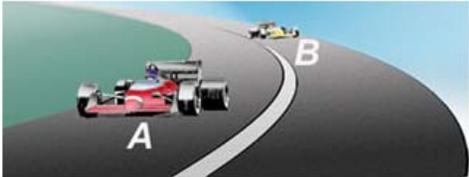


Figure 6.1

Q Two cars are rounding curves. Both cars are traveling at a constant speed of 40 kilometers per hour. Car A is rounding a very sharp curve and car B is rounding a gradual curve. Which of the following are true regarding the motion of the cars?

- Cars A and B both have zero acceleration because their speeds are not changing.
- Car A and car B have the same acceleration because they have the same speed.
- Car A is accelerating more than car B because it is changing direction at a faster rate.
- Car A and car B have the same acceleration because they have the same velocity.

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C550105000000368&courseID=00065BF1B6260A8F2C730...

Answer Feedback

Correct!

Correct. Even though they have the same speed, car A is changing direction faster (sharper curve), so it has a greater acceleration.

For more information:

- [Review the One More Definition section](#)

Interactive Reference:

Primarily the main portion of the online web-based SciPack module. This includes the general narrative, images, audio, check your thinking, slideshows, and animations or QuickTime movies. It constitutes the main portion of the SciPack content. The audio button is professionally recorded audio of the narrative already existing on the page.

Interactive Reference Example 1 (Force and Motion):

The screenshot shows a web browser window with the URL <http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C55010500000036&courseID=00065BF1B6260A8F2C73...>. The page header includes the NSTA SciPacks logo and the title "Force and Motion Position and Motion" with a "2 OF 9" indicator. A navigation bar contains "Home", "Ask the Wizard", "Reset Page", "Previous", and "Next" buttons. A left sidebar lists various topics under "Position and Motion", including "Introduction", "Position", "Motion", and "Credits". The main content area features an audio player at the top, followed by the section "Questions to Ponder". The text asks for real-life situations where specifying an object's position is important. Below the text is a video player showing an air traffic controller at work, with a caption "Inside an air traffic controller tower." and a "3 of 7" indicator. A text box at the bottom explains that air traffic controllers need precise position information.

Position and Motion

- Introduction
- Position
 - Position of Objects
 - Animation
 - Describing the Position
 - Alternate Descriptions
 - Questions to Ponder
- Motion
- Changes in Motion
- Tying it All Together
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Questions to Ponder

Can you think of other real-life situations in which specifying an object's position would be important? We've talked about being lost at sea and aiming for satellites, but surely there are other applications, right? Write down a few.

If you're stuck for ideas, play the following slideshow and get a few hints.

Inside an air traffic controller tower.

3 of 7

Air traffic controllers need precise position information, without which a whole lot more of us would be taking the bus.

Interactive Reference Example 2 (Force and Motion):

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C5501050000036&courseID=00065BF1B6260A8F2C73...

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 - Clarifying Speed
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 - Challenge
 - One More Definition
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- Credits

Check Your Thinking

The following is a list of objects. Figure out which ones are accelerating and which ones aren't. Some are easy and some are not so easy. Press the button to see the answers.

The Moon



Figure 4.4

Check Your Thinking

A tree falling

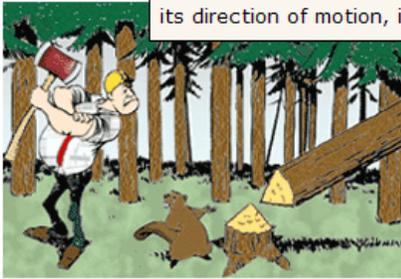


Figure 4.5

Check Your Thinking

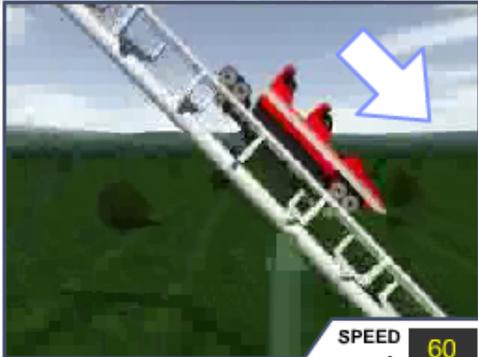
The moon is moving in a circular path around the Earth, and thus changing direction. Because the moon is changing its direction of motion, it's accelerating.

Interactive Reference Example 3 (Force and Motion Animations)

NSTA SCIENCE ANIMATION: MOTION RELATED TO SPEED INSTRUCTIONS

1. Watch the car on the roller coaster pass through the six zones of different slope.
2. When the car passes through all six zones, you can use the playback to revisit the six zones to see the vector representing the car's speed and direction.

RESET
PAUSE



SPEED 60 mph

ZONES ONE TWO THREE FOUR FIVE SIX



PLAYBACK

NSTA SCIENCE ANIMATION: Velocity & Speed INSTRUCTIONS



AVERAGE SPEED **SPEED**

Well, Derek, Tank the Tortoise had a considerable challenge with speed and the hare, Mel, had to overcome his challenge with overall average speed.

CONTROL PANEL
 START
 STOP
 RESET



Pedagogical Implications

The pedagogical implications component provides grade-band specific information tied to that science content topic area. This part of the SciPack is designed to help teachers recognize the level of sophistication appropriate for their students, identify or diagnose students' preconceptions, and employ strategies that are most effective for the particular ideas they teach. It is not interactive with respect to embedded questions and simulations, but provides a visual map that shows the relationship between both the National Science Education Standards and the Benchmarks for Scientific Literacy as well as the narrative, which is broken out by the following grade bands: K–2, 3–5, 6–8, and 9–12.

Pedagogical Implications Example 1 (Force and Motion, Grades 3–5):

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C5501050000036&courseID=00065BF1B6260A8F2C73...

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3–5 Strand Map

In grades 3–5, students can start to develop their understanding of the relationship between forces and motion. Their experiences should still be largely descriptive, but they should become increasingly experimental and quantitative as students develop their measurement skills.

The partial strand map below shows the ideas (colored blue) to be learned in grades 3–5, the ideas that come before them in grades K–2, and the later ideas they lead to in grades 6–8. Statements in each box describe ideas with which students should "walk away" from their learning experiences. The arrows mean that understanding one idea can contribute to understanding another. At the bottom of the map are three labels—"Describing Motion," "Changes in Motion," and "Forces." These are the major strands of ideas that should develop over the grades. For each of these strands, we'll talk about the specific ideas included, insights from research, and possible approaches for instruction. Of course, sometimes there will be overlap among different strands. They are really just an easy way to organize our discussion, and they don't imply that you should teach them separately.

Move your mouse over the boxes below to see the text or select the following link for a full sized version of the image:
[3-5 Strand Map](#)

6-8

- The motion of an object can be described by its position, direction, duration, and speed. That motion can be measured and measured on a graph. (NSES 6-8)
- A subject that is being subjected to a force will continue to move at a constant speed and in a straight line (NSES 6-8). An unbalanced force acting on an object changes its speed or direction or both. (NSES 6-8)
- If more than one force acts on an object, the net force that the forces will combine to cause the motion depends on their direction and magnitude. (NSES 6-8)

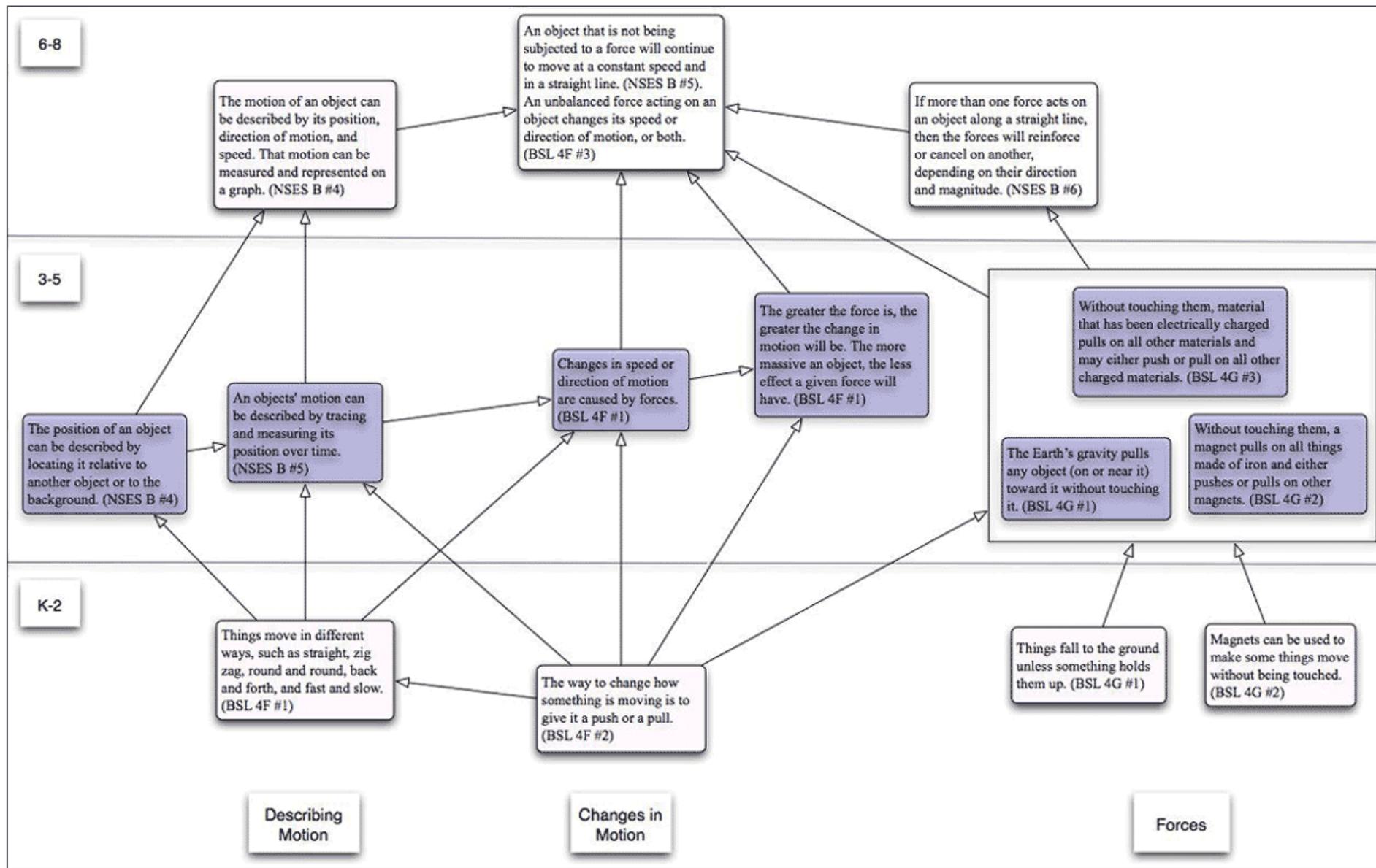
3-5

- The motion of an object can be described by its position, direction, duration, and speed. (NSES 3-5)
- An object's motion can be described by its position and direction. (NSES 3-5)
- Change in speed or direction of motion can be caused by forces. (NSES 3-5)
- The greater the force, the greater the change in motion will be. (NSES 3-5)
- Without touching them, magnets that have been rubbed together will pull on all other charged materials. (NSES 3-5)
- Without touching them, magnets that have been rubbed together will pull on all other charged materials. (NSES 3-5)
- Without touching them, magnets that have been rubbed together will pull on all other charged materials. (NSES 3-5)

K-2

- Things move in different ways, such as straight, zigzag, round and round, back and forth, and fast and slow. (NSES K-2)
- The way to change how something is moving is to give it a push or pull. (NSES K-2)
- Changes fall to the ground unless something holds them up. (NSES K-2)
- Magnets can be used to make some things move without being touched. (NSES K-2)

Describing Motion **Changes in Motion** **Forces**



Science Pedagogical Implications

- + Introduction
- + Grades K-2
- + Grades 3-5
 - + 3-5 Strand Map
 - + Describing Motion
 - + Forces
 - + Changes in Motion
- + Grades 6-8
- + Grades 9-12
- + Further Reading
- + SciGuide

Describing Motion

Students should build on their observations and experiences in K-2 to make more exact descriptions of first the position and then the motion of objects. The *National Science Education Standards* recommends that by the end of fourth grade, students should know the following:

- The position of an object can be described by locating it relative to another object or to the background.
- An object's motion can be described by tracing and measuring its position over time.

Students should have experiences that show them that both distance and direction are needed to accurately describe position (many young students think that only distance is needed). The tortoise and hare simulation we did in the Science Object is a good activity (although the story of the tortoise and hare might be more familiar to adults than elementary students). Students at this age may be more interested in something like a treasure hunt. To emphasize that they need to describe both distance and angle, you could start out by giving them only the distance to the treasure and letting them struggle for a while.

You will also want to find ways to help students care about exact measurements of position. As we said in the Science Object,

"It's nice to know where a satellite is at any given time, especially if you want a good television signal. If you're lost at sea, it might be comforting to know that your Global Positioning System will help the proper people find you. If you want the Hubble Space Telescope to look at a particular object in the sky, it would help if you could give the telescope the proper position of that object."

Of course, we were thinking about things you might care about. You should try to draw on your own students' interests. In the Science Object, we also talked about some situations in which it might make sense to locate positions using a grid with an x and y axis (or latitude and longitude on a globe). If you want to explore this with your students, make sure that they have had some experience with x and y axis grids (otherwise, it will probably just add unnecessary confusion).

Once students can give accurate descriptions of position, they can begin measuring changes in position over time (speed and direction) to describe motion. A good activity is to use a stopwatch and ruler to make measurements of balls moving at different speeds, which we did in a simulation in the Science Object. It is worth noting that students will need at least a basic understanding of ratios (because speed is a property that depends on the ratio between time and distance). You don't need to worry about accurate descriptions of changes in speed or direction (acceleration). That will come later.

In the Science Object, we discussed the term "velocity" as implying both the speed and the direction of an object's motion, but students may not immediately grasp the meaning of that word (they often confuse it with speed). Either way, an understanding that both speed and direction are needed to accurately describe motion is more important than vocabulary.

Of course, one of the major reasons for worrying about descriptions of position and motion is so that students can start to explore more systematically the changes in motion caused by pushes or pulls or other forces. We'll talk more about that in the Changes in Motion strand.

Science Pedagogical Implications

- + Introduction
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 - + 3-5 Strand Map
 - + Describing Motion
 - + Forces
 - + Changes in Motion
- + Grades 6-8
- + Grades 9-12
- + Further Reading
- + SciGuide

Forces

Students should continue to develop ideas about specific forces that can act at a distance. They can build on observations of concrete pushes and pulls they made in K-2 to understand that Earth, magnets, and electrically charged materials can also exert pushes and pulls on objects, and they do so without touching them. *Benchmarks of Science Literacy* recommends that by the end of fifth grade, students should know the following:

- The Earth's gravity pulls any object toward it without touching it.
- Without touching them, a magnet pulls on all things made of iron and either pushes or pulls on other magnets.
- Without touching them, material that has been electrically charged pulls on all other materials, and may push or pull other charged materials.

Similarly, the *National Science Education Standards* recommends that by the end of the fourth grade, students should know the following:

- Magnets attract and repel each other and certain kinds of other materials.

These ideas will also help students build a more scientific view of forces in later grades. (Of course, ideas about these specific forces will also lead to understanding about universal gravitation and electromagnetism, but that is not our focus here.) Although less concrete than pushes and pulls, these ideas are still basic observations. There's no need to worry about the strength of the forces or the details of how they behave. The point here is that some basic experiences with these forces is an important part of developing the general ideas of force.

Experience with these forces can also help students challenge the common idea that only animate objects can exert a force. Through observations of the effects of Earth's gravity, magnets, and electrically charged material, students can expand their conception of what counts as a "force." In the discussion below for the *Changes in Motion* strand, students can explore how these forces change the motion of objects.

Science Pedagogical Implications

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Changes in Motion

Students can begin to understand that pushes and pulls are forces (just like gravity, magnetism, and the electric forces described above), and that objects change their motion because of forces. Students can also start to develop the qualitative notion that changes in motion depend on the size of the force and the mass of the object. *The National Science Education Standards* recommends that by the end of the fourth grade, students should know the following:

- The position and motion of objects can be changed by pushing and pulling. The size of the change is related to the strength of the push or pull.

Similarly, *Benchmarks for Science Literacy* recommends that by the end of the fifth grade, students should know the following:

- Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive a given object, the less effect a given force will have.

The 3–5 strand map shows that ideas in the Describing Motion strand will contribute to learning about changes in motion. Students should be using those skills to apply forces in many different ways and observe the result. A key point will be for students to use their observation and description skills to understand the difference between constant motion and changing motion. To fully understand this, students should carefully watch objects change motion as they apply different forces. They should also recognize that if there's a change in motion, there must be some force acting. Attention to the time of a force's action will be important so that students can see the difference between an impulse force and a continuous force (a quick shove does not continue to apply a force after the contact is over, but gravity does exert a continuous force).

Students will likely have some intuitive ideas that don't match the scientific way of seeing forces and their relationship to motion. Of course, these intuitive ideas do match students' everyday observations and experiences, so it will be difficult to get them to change their ideas. You should be trying to give them direct experiences that their ideas fail to fully explain. For example, students often fail to recognize blocking forces as actually being forces, so you should include some experiences with stopping objects, and explicitly address that as a change in motion caused by a force.

Students also struggle with the relationship among a force's strength, an object's mass, and the amount of change in motion. They may think that the same push or pull on an object will result in the same motion regardless of the mass of the object or that any amount of force applied to an object will make it move the same. To challenge these ideas, students should have lots of experiences exerting bigger and smaller pushes and pulls on bigger and smaller objects. In the Science Object, you played with an animation in which you could exert forces of different strengths on balls of different masses. This kind of exploration is a good idea for students, too.

Not all students' intuitive ideas need to be challenged at this stage, and students in grades 3–5 should still be dealing with pretty simple situations. Detailed descriptions of complex changes in motion and the notion of balanced and unbalanced forces should wait until later grades.

Pedagogical Implications Example 2 (Force and Motion, Grades 6–8):

Force and Motion
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6–8 Strand Map

At this stage, students are ready deal with more complex situations and more exact descriptions of changes in motion. Students can also begin to explore balanced forces and the effect of net forces. Newton's first and second laws should be introduced in a qualitative form. Simple quantitative problems are okay too, and tables and graphs can help students begin to see relationships between variables. But a solid understanding of the quantitative relationship among forces and motion is not important at this stage.

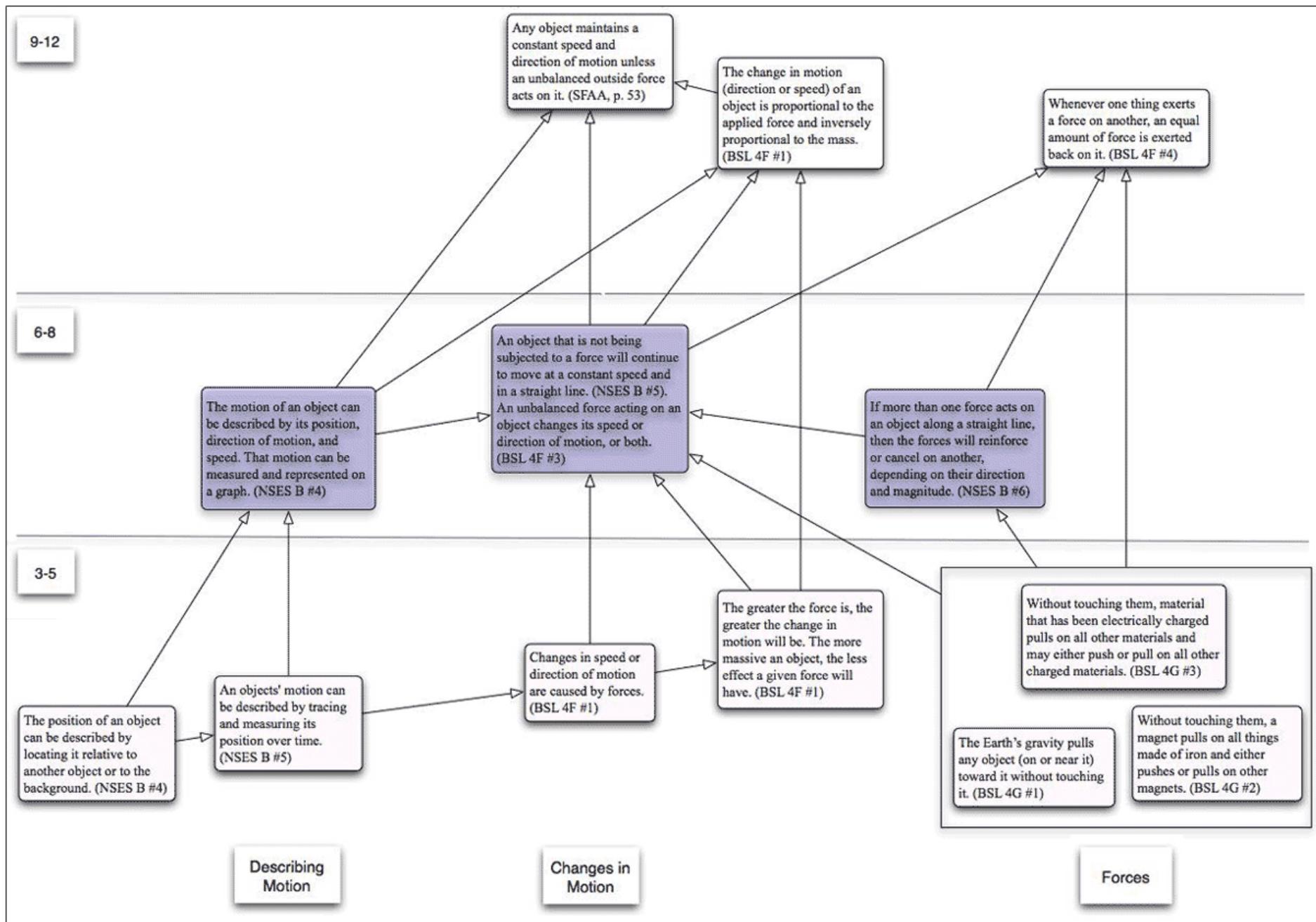
The partial strand map below shows the ideas (colored blue) to be learned in grades 6–8, the ideas that come before them in grades 3–5, and the later ideas they lead to in grades 9–12. Statements in each box describe ideas with which students should "walk away" from their learning experiences. The arrows mean that understanding one idea can contribute to understanding another. At the bottom of the map are three labels– "Describing Motion," "Changes in Motion," and "Forces." These are the major strands of ideas that should be developed over the grades. For each of these strands, we will talk about the specific ideas included, insights from research, and possible approaches for instruction. Of course, sometimes there will be overlap among different strands. They are really just an easy way to organize our discussion, and they don't imply that you should teach them separately.

Move mouse over the boxes below to see the text or select the following link for a full sized version of the image:
[6–8 Strand Map](#)

The diagram is a flowchart showing the progression of concepts in force and motion across three grade levels: 3-5, 6-8, and 9-12. It is organized into three vertical columns representing different strands: Describing Motion, Changes in Motion, and Forces. Arrows indicate the flow of learning from lower grades to higher grades and between related concepts.

- Grade 3-5 (Bottom Row):**
 - Describing Motion:** "The position of an object can be described by locating it relative to a reference object on the background." (MS-2-304)
 - Changes in Motion:** "An object's motion can be described by its position, time." (MS-2-305)
 - Forces:** "The Earth's core by pulls any object toward it." (MS-4-301) and "When a walking person makes a turn, all things made of firm and other parts resist their own magnetism." (MS-6-302)
- Grade 6-8 (Middle Row):**
 - Describing Motion:** "The motion of an object can be described by its position, direction of motion, and speed. The motion can be measured and represented as a graph." (MS-2-306)
 - Changes in Motion:** "Changes in speed or direction of motion are caused by forces." (MS-2-307)
 - Forces:** "When the net force acting on an object along a straight line, then the forces will continue to cause an acceleration in that direction." (MS-2-308)
- Grade 9-12 (Top Row):**
 - Describing Motion:** "Any object maintains its constant speed and direction of motion unless an unbalanced force acts on it." (MS-2-309)
 - Changes in Motion:** "The change in motion (direction or speed) of an object is proportional to the applied force and inversely proportional to its mass." (MS-2-310)
 - Forces:** "Whenever one object exerts a force on another, an equal reaction force is exerted back on it." (MS-2-311)

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Describing Motion

Students should be making more and more precise descriptions of changing motion, moving beyond simple descriptions of changing position. The *National Science Education Standards* recommends that by the end of the eighth grade, students should know the following:

- The motion of an object can be described by its position, direction of motion, and speed. The motion can be measured and represented on a graph.

In the Science Object, we spent some time discussing the term "acceleration." But students of all ages have difficulty with the meaning of this word. In particular, they are likely to think of acceleration only in terms of speeding up, and as only acting in a straight line in the direction of the motion. Students' experiences should challenge these notions, and you should help them understand what scientists mean when they say "acceleration"; but in the end, correct use of vocabulary is not the most important goal. Thus, the use of terms should wait until students have a solid grasp of the concepts, and students should be continually challenged to explain what they mean in their own language. If you think back to the Science Object, you'll remember that we gave you lots of experiences with changing speeds and directions before we bothered to call those changes "accelerations," and many of the questions we asked used everyday language as well.

The point is that students should be measuring and describing lots of changes in motion (slowing down, speeding up, changing direction, and so forth). Making clear distinctions among these different kinds of changes is important; many students think of objects as either at rest or moving. A critical step in grades 6-8 will be for students to solidify their understanding of the distinction between constant and changing motion. One possible approach for this is to have students look at strobe photographs of objects in both constant and changing motion, describing and making arguments about what they see.

Select the "Next" button at the top of this page to continue on to Forces.

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Forces

In the earlier grades, the ideas in this strand focused on simple observations and ideas about specific forces. The major idea to be grasped at this level is the notion of multiple forces reinforcing or balancing one another. The *National Science Education Standards* recommend that by the end of the eighth grade, students should know the following:

- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on direction and magnitude.

Students of all ages believe that if there is no motion then there is no force acting, so the idea of forces canceling each other out may be difficult. Experience identifying the forces that are acting on an object will be important. For example, you could present a large object such as a beach ball to the class, then have students push on either side of it. Then they can then observe that even though each side is exerting a large force, the ball may not move.

Students' understanding of these situations will directly contribute to their growing understanding of Newton's second law, described in the next section. Indeed, at this point, instruction around the idea in this strand and the *Changes in Motion* strand should be tightly coordinated.

Select the "Next" button at the top of this page to continue on to *Changes in Motion*.

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- SciGuide

Changes in Motion

Students can begin to learn about Newton's first law and the concept of inertia. This is a very difficult idea that will have to be reinforced over time with multiple experiences. The *National Science Education Standards* recommend that by the end of the eighth grade, students should know the following:

- An object that is not being subjected to a force will continue to move at a constant speed in a straight line.

The idea in this standard also implies that an object at rest (really just a special case of constant motion, with a constant speed of zero) will remain at rest unless acted on by a force. Students will probably be willing to accept this formulation of the idea, but some students may confuse inertia and friction, thinking that friction rather than inertia resists motion. Students will eventually need to understand that inertia is a property of an object related to its mass, and frictional force is an interaction between two objects.

The notion that an object will continue moving with no change in speed or direction unless acted on by a force will likely be more difficult for students. Students tend to believe that the only "natural" state of an object is to be at rest. And many studies reveal that even students who have been through an introductory physics course believe that motion requires a force in the same direction and that a force is needed to keep an object moving with a constant speed. This isn't really surprising. In everyday life, objects do come to a stop. Overcoming this notion will require more than just direct experience. In the Science Object, we did an activity in which a ball rolled down ramps of different shapes; then, we reasoned that if the ramp were flat on one side, the ball would keep rolling forever. This could also be a very effective exercise for middle-school students.

Another way to help students make the transition from these intuitive notions to the scientific view is by addressing the role of friction. As stated in *Science for All Americans*,

"In most familiar situations, frictional forces complicate the description of motion, although the basic principles still apply" (p. 53).

You can provide students with a series of experiences that reduce the effect of friction. In the Science Object, we looked at an animation of a ball rolling across different surfaces and noticed that the ball would slow down less on surfaces that created less friction. You can do similar activities with your students and gradually help them to think about what would happen to the object if there were no friction (it would keep moving forever). This requires abstract reasoning, and students should be given lots of time to raise questions and discuss their ideas.

Middle-school students should also enhance their understanding of Newton's second law. *Benchmarks for Science Literacy* recommends that by the end of the eighth grade, students should know the following:

- An unbalanced force acting on an object changes its speed or direction of motion, or both.

Similarly, the *National Science Education Standards* recommends that by the end of the eighth grade, students should know the following:

- Unbalanced forces will cause changes in the speed or direction of an object's motion.

Now is the time to explore changes in both the speed and direction of motion. Students should be ready to talk about these changes as "acceleration," but you should take care not to assume they intuitively know the definition (see the discussion about acceleration in the *Describing Motion* strand). Also, students will need to draw on their understanding of the effect of multiple forces (as discussed in the *Forces* strand above) before they approach this idea (the map shows that the relationship among these ideas). The practice of identifying all the forces acting on an object will be key and deserves significant attention and practice for its own sake.

Pedagogical Implications Example 3 (Plate Tectonics):

NSTA
SCIPACKS

Plate Tectonics
Pedagogical Implications

1 OF 4

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Pedagogical Implications

- Learning About Plate Tectonics
 - Introduction
 - Grades K-4
 - Grades 5-8
 - Grades 9-12

Introduction

The following four essays are written for educators intending to teach the subject of Plate Tectonics to students in grades K-12. The essays are broken down into four grade level bands that correspond to the *National Science Education Standards*^[1]; K-4, 5-8 and 9-12. The concept of Plate Tectonics is complex and is generally taught to students grades 6-12; therefore the K-4 essay focuses mainly on concepts children should understand prior to learning plate tectonics. While the essays do stand alone, they are also complimentary. They are intended to convey how students come to understand the key concepts of Plate Tectonics as they progress through the grade levels.

The subject matter for the essays is based on five "Key Ideas" that appear in this SciPack:

1. The interior of the earth is hot, under high pressure from gravitational pull, and denser than its rocky crust. The earth is layered with a relatively thin crust; hot, deformable and convecting mantle, and liquid outer core, and solid metallic, denser inner core.
2. The earth's continents and ocean basins are made up of plates consisting of the crust and the upper part of the mantle. One plate can consist of both continental and oceanic crust. These plates move very slowly (an inch or so per year) on the hot, deformable layer of the mantle beneath them. The outward transfer of earth's internal heat drives convection circulation in the mantle which together with gravitational pull on the plates themselves causes the plates to move.
3. Plate interactions can be slow and steady or abrupt. In different ways, they may push against each other, pull apart from one another, or slide past one another.
4. Plate margins are active. Plates pushing against one another can cause earthquakes, volcanoes, mountains, and very deep ocean trenches. Plates pulling apart from one another can cause smaller earthquakes, rising magma, volcanoes, and oceanic valleys and mountains from sea-floor spreading. Plates sliding past one another can cause earthquakes and rock deformation.
5. Plate tectonics provide a unifying framework for understanding earth processes and history, and are supported by many lines of evidence. Over geologic time, plates move across the globe creating different continents (and positions of continents).

Much of what is known about learning plate tectonics comes from general research regarding how students learn about the Earth^[2]^[3]. However, there are a small number of studies that address learning and misconceptions associated with the topic of plate tectonics.^[4]^[5]^[6]^[7] In addition to published studies, many faculty members have provided anecdotal information on web pages and syllabi for Solid Earth courses. Only those misconceptions that were consistently identified are used in this document. Information regarding benchmarks and standards is drawn from several sources; *National Science Education Standards*¹, *Benchmarks for Science Literacy*,^[8] *Science for All Americans*^[9] and *The Atlas for Science Literacy*^[10]

[1] National Research Council (1996). *National Science Education Standards*. Washington DC: National Academy Press

[2] Phillips, W. (1991) *Earth Science Misconceptions In NASA Teacher Education Program*. Retrieved January 2005 from, <http://k12s.phast.umass.edu/~nasa/misconceptions.html>

http://scipacks.nsta.org/?curID=00065BF1B6260BB3CA4A01050000052&courseID=00065BF1B6260BB3CB6C...

NSTA SCIPACKS Plate Tectonics Pedagogical Implications 2 OF 4

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Pedagogical Implications

- Learning About Plate Tectonics
- Grades K-4
 - K-4 Strand Map
 - Learning About Plate Tectonics: Grades K-4
- Grades 5-8
- Grades 9-12

Move your mouse over the boxes below to see the text or select the following link for a full sized version of the image:
[K-4 Strand Map](#)

Figure 1. Concepts students in grades K-4 should learn about the Plate Tectonics. Arrows indicate how concepts are connected to further learning. This chart is based on the *Atlas for Science Literacy*¹⁰, page 51.

3-5

How fast things move differs greatly. Some things are so slow that their journey takes a long time.

Things change in a steady repetitive, or irregular way - or sometime in more that one way at the same time.

Prerequisite: Things on or near the earth are pulled toward it by the earth's gravity.

K-2

Some changes are so slow or so fast they are hard to see.

Change is something that happens to many things.

Scientists develop explanations using observations (data). Good explanations are based on evidence from investigations. NSES pg. 123

Select the "Next" button at the top of this page to continue on to *Learning About Plate Tectonics: K-4*.

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http://scipacks.nsta.org/?curID=00065BF1B6260BB3CA4A010500000052&courseID=00065BF1B6260BB3CB6C0...

NSTA
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Plate Tectonics
Pedagogical Implications

2 OF 4

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Pedagogical Implications

- Learning About Plate Tectonics
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 - Grades 5-8
 - Grades 9-12

Learning About Plate Tectonics: K-4

While learning about plate tectonics does not typically begin in elementary school, students do begin to learn important ideas essential to understanding the concept. According to the *Benchmarks for Science Literacy*⁸, "an integrated picture of the earth has to develop over many years, with some concepts being visited over and over again in new contexts and greater detail." In the early stages of learning, studying the specific concepts of plate tectonics and how it affects the face of the earth serves little purpose, however children should become familiar with their surroundings (i.e. mountains, volcanoes, etc.) and the idea that things change over time⁸. Children in these grades should also be introduced to scientific inquiry. They should learn how data and observations can be used to construct reasonable explanations for observable phenomenon¹. These concepts are essential to understanding the complex processes involved in the Plate Tectonic theory and will be revisited as a child continues to learn about plate tectonics.

A fundamental misconception that many children, and adults alike, hold is that the earth was always as it is now. They do not understand the earth has changed over billions of years. Also children may believe that any and all changes that have occurred happened during catastrophic events². Teachers should be aware that children may hold different ideas of how and if the earth surface has changed over time and direct their lessons to address these misconceptions in the earliest stages of learning.

Students in the elementary grades should be actively involved in scientific inquiry. At this age, they should be presented with activities that allow them to make and record observations and begin conducting simple investigations and posing simple explanations from those observations⁸. Investigation activities might focus on change through time such as keeping a science journal where students record how their surroundings change through a school year and why they might be changing. Students should be encouraged to record information about the rate of change.

To assess learning, teachers will need to engage students in scientific inquiry. Journals can be evaluated and younger students should talk about observations and draw what they see and think. Older students can begin using instruments and record measurements and draw conclusions from those measurements¹. The focus of evaluation should not be placed on finding the correct explanation from an inquiry activity, but rather determining a student's ability to recognize that change has taken place and provide reasonable explanations using their observations.

By the time students leave fourth grade they should have good understanding that things change through time and change may happen slowly or fast. They should understand that evidence from observations is used to develop explanations of scientific phenomenon.

Appendix D:
How to Create NSTA Web-Based Learning Content Modules

How to Create NSTA SciPacks and Science Objects

What Is a SciPack?

Each SciPack is a relatively short learning experience designed to enhance teachers' understanding of a small set of particular ideas. These ideas are based on the goals for science literacy in the national standards (*National Science Education Standards, Science for All Americans, Benchmarks for Science Literacy, and the Atlas of Scientific Literacy*). Thus, each SciPack will help teachers understand science content that directly relates to what they need to teach.

In addition to learning experiences focused on science content, each SciPack will also provide grade-level specific information and resources tied to that content. This part of the SciPack will be designed to help them recognize the level of understanding appropriate for their students, identify or diagnose students' misconceptions, and employ strategies that are most effective for the particular ideas they teach. Example titles of SciPacks are:

- The Universe
- Plate Tectonics
- Forces and Motion

Rather than being a collection of activities that fit under some topic heading, a SciPack is a carefully structured set of strategies designed to lead teachers to an understanding of a very specific idea or skill. The process of determining the appropriate idea or skill for the teacher to learn begins with close study of national standards. The following is an example of a preliminary list of standards for a SciPack on Forces and Motion:

Forces and Motion:

From AAAS Benchmarks and Science for All Americans

An unbalanced force acting on an object changes its speed or direction of motion, or both...4F 6-8 #3

The change in motion of an object is proportional to the applied force and inversely proportional to the mass. 4F 9-12 #3

Whenever one thing exerts a force on another, an equal amount of force is exerted back on it. 4F 9-12 #4

In most familiar situations, friction between surfaces brings forces into play that complicate the description of motion, although the basic principles still apply. (SFAA, p. 53)

From National Science Education Standards

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph. 5-8/PS-B#1

An object that is not being subjected to a force will continue to move at a constant speed in a straight line. 5-8/PS B#2

If more than one force acts on a object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion. 5-8/PS B#3

Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object. 9-12/PS B#16

The standards for a given SciPack are then broken down into separate Key Ideas. The Key Ideas may differ slightly from the standards, but only as a result of careful analysis and consensus by the development team. Each Key Idea is addressed in a self-contained instructional component, called a Science Object that is designed to develop an understanding of a Key Idea.

A given SciPack is composed of three to five Science Objects that together address all the Key Ideas. For example, a Science Object within the Forces and Motion SciPack would focus on the following Key Idea:

“The position of an object must be described relative to some other object. The motion of an object can be described by its direction and speed. Velocity is a measure of both an object’s speed and its direction (and can be described by vectors). Constant motion means that the direction and speed remain the same. Changes in motion (direction or speed) are called accelerations.”

A later Science Object within the Forces and Motion SciPack would focus on a subsequent Key Idea:

“An unbalanced force acting on an object changes its speed or direction of motion, or both. Any object maintains a constant speed and direction of motion unless an unbalanced outside force acts on it. Inertia is the name given to the tendency of objects to maintain a constant speed and direction of motion (velocity) in the absence of an unbalanced force. In most familiar situations, frictional forces can complicate the analysis of motion, although the basic principles still apply.”

Each SciPack also contains a “Pedagogical Implications” component at the end of the SciPack that provides information and resources related to:

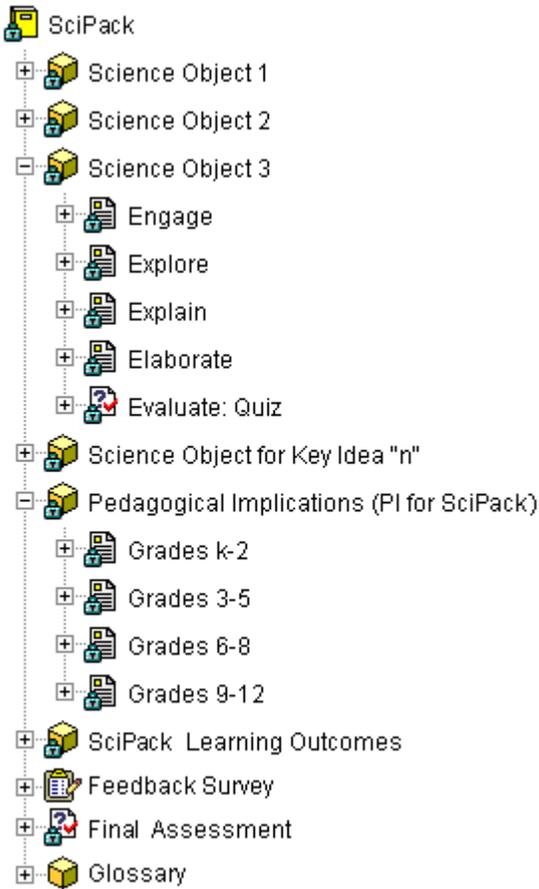
- The level of understanding appropriate for students at a particular grade level
- The sequence and relative emphasis with which concepts should be presented
- Common student preconceptions or difficulties
- A sense of which instructional strategies are most likely to be effective

Consequently, educators will learn not only critical science content drawn from the standards, but also develop a sense of how that content should be presented to students (relevant to their specific grade level).

The instruction within each Science Object will be approximately 2 hours long and will employ a learning cycle of Engagement, Exploration, Explanation, Elaboration, and Evaluation. As part of the Evaluation stage, each Science Object will include a quiz at the end of the object to help the teacher formatively assess his or her level of understanding. In addition, a final assessment will be available after completing all the Science Objects within a SciPack. The final assessment is summative in nature and will assess the teachers' understanding of all the Key Ideas for the SciPack at a pass/fail level.

The Learning Content Management System (LCMS) used to develop and deliver the SciPacks will allow the curriculum writer to work in Microsoft Word. Using Word document templates, the NSTA Course Developer can put the content from the Word document into an online course. As the content is being imported into the course, the navigation structure for the course is created dynamically, and the metadata tags are automatically inserted for content tracking and retrieval.

Below is a schematic of the structure of SciPack, comprised of multiple Key Ideas (or Science Objects):



- SciPack: Provides 10-hour learning experience.
- Free Navigation within SciPack during subscription period.
- Each Science Object follows a 5E learning cycle.
- Each Science Object will be 2 hours long.
- Key Idea “Quiz” at end of each Science Object (not graded).
- To earn SciPack credit each Quiz must be attempted and the Final Assessment must be passed within 3 tries.
- 70% to pass Final Assessment after 3 tries at end of the entire SciPack.

Below is review of the production process workflow, which is then followed by the inquiry-design templates, all of which is created to ensure the most consistent quality and effectiveness of each SciPack.



SciPack Production Timeline

Review SciPack Production Model

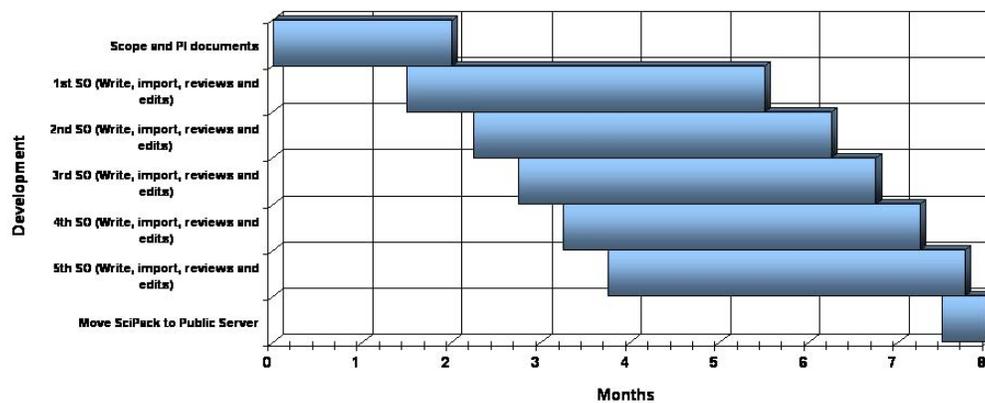
- Iterative Production Process
- Production Timeline
- Review Consultant and NSTA Roles

2



SciPack Production Timeline

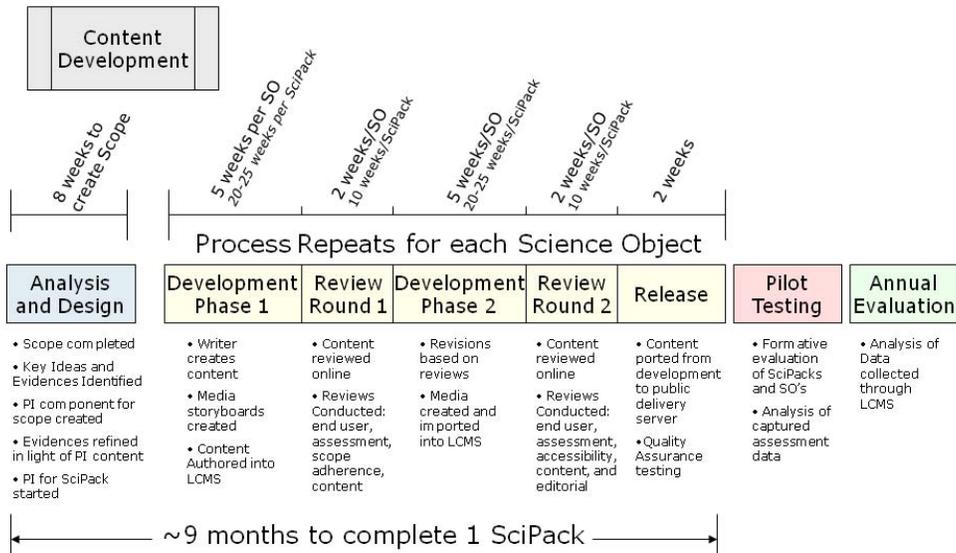
Single SciPack Production Timeline



3

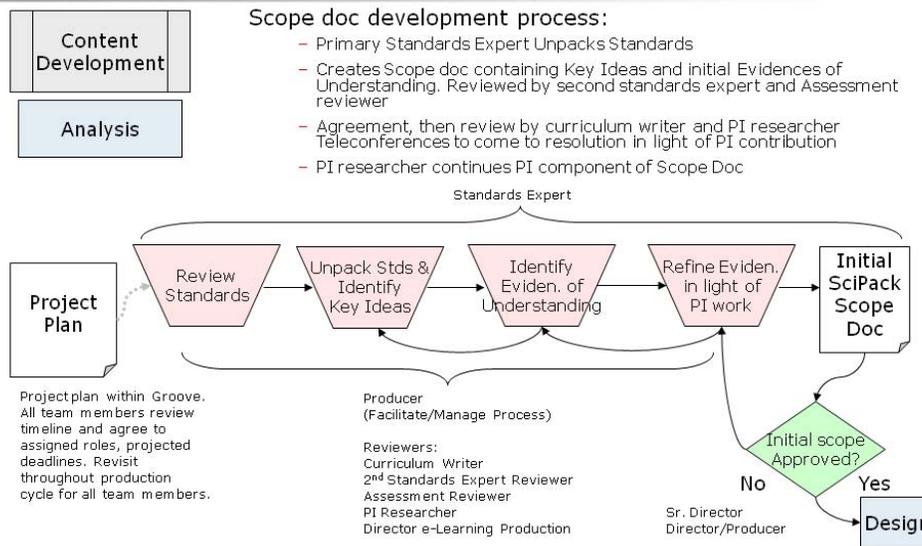


High Level Process Flow Single SciPack



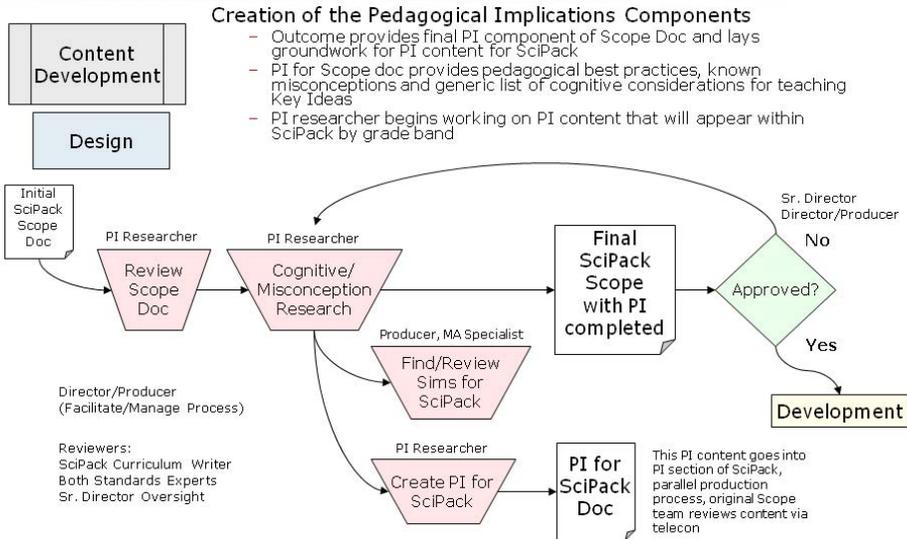
4

Analysis and Design Phases (Initial Scope)



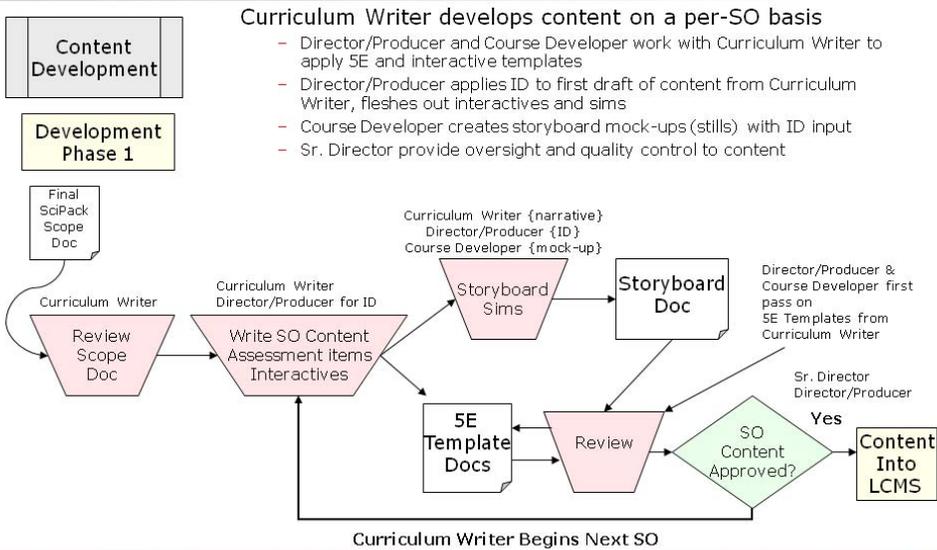
5

Analysis and Design Phases (Scope with PI)



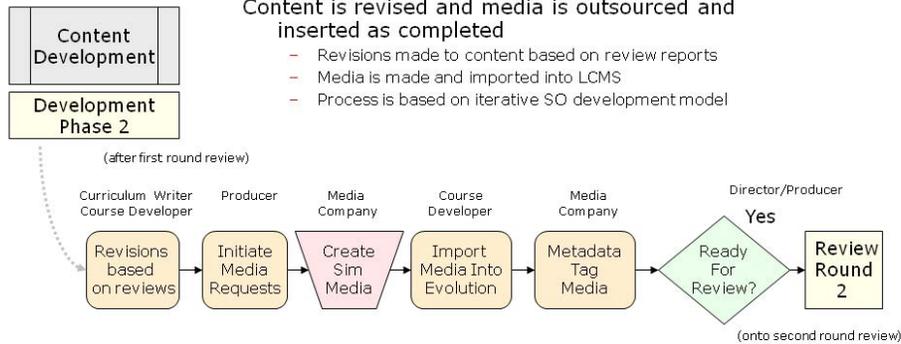
6

Development (Phase 1) Curriculum Writer content



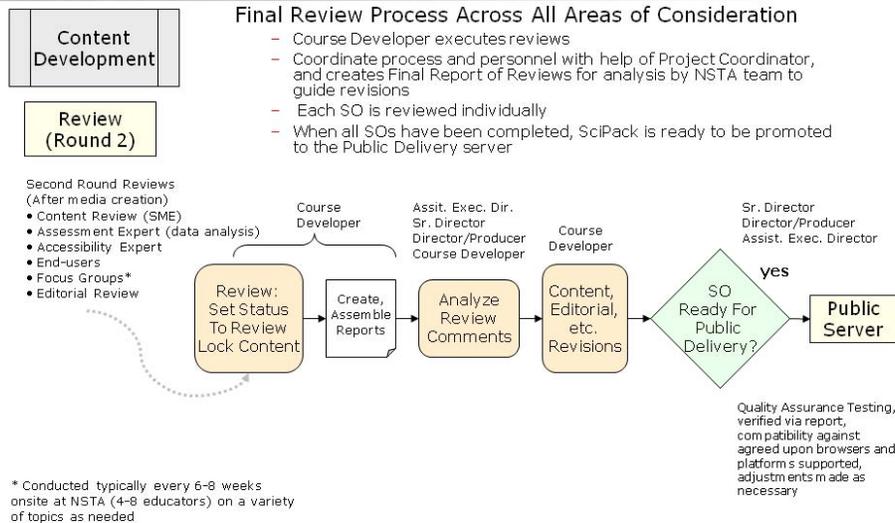
7

Development (Phase 2) Outsource Media Creation



10

Review (Round 2), Final Revisions, and Release



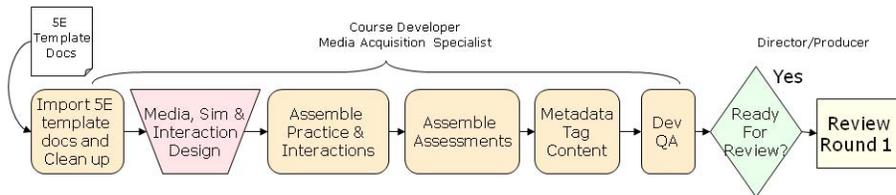
11

Development (Phase 1) Import content into LCMS



Content is inserted into Learning Content Management System

- Process is based on iterative SO development model
 - 5E Templates are imported into LCMS, assessment items assembled, and mock-ups of interactives created
 - Curriculum writer begins next SO in parallel



Concurrent Process—Curriculum Writer Begins Next SO

Review (Round 1) Prior to Media Creation



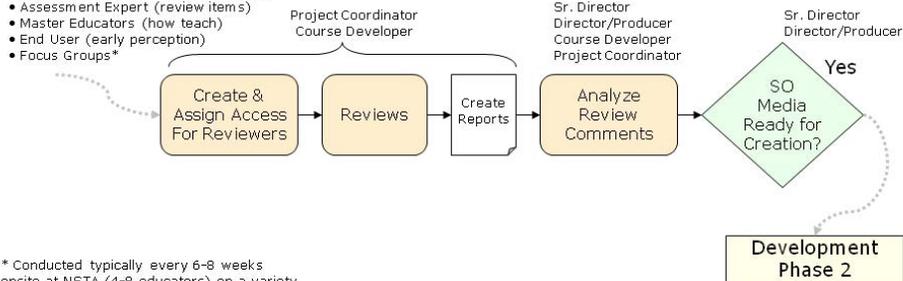
Project Coordinator and Course Developer Execute Review Process

- Coordinate Process, Personnel, and Final Report of Reviews for Analysis by NSTA team (Executive Producer, Producer, Course Developer)
- Each SO is reviewed individually (two to four reviews by educators), periodic focus groups on-location at NSTA
- SO is reviewed by Content, Standard, and Assessment Experts

First Round Reviews

(before media creation)

- Content Expert (SME)
- Standards Expert (Scope adherence)
- Assessment Expert (review items)
- Master Educators (how teach)
- End User (early perception)
- Focus Groups*



* Conducted typically every 6-8 weeks onsite at NSTA (4-8 educators) on a variety of topics as needed

Developing a Science Object

To aid in standardization and quality across the development of numerous SciPacks, writers must apply an instructional template for the development of each Science Object. Each Science Object will contain all five stages of the 5E learning cycle: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Guidelines and examples for each of the stages of this learning cycle are outlined in the next section.

Curriculum writers, working in conjunction with the course developer, content expert, and producers must complete each of the stages to produce a viable Science Object. However, depending on the Key Ideas being addressed, the development team may need to tweak the application of the learning cycle. For example, every Science Object will begin with Engage and end with Evaluate, but the other stages may receive varying degrees of treatment or sequencing within the Science Object (e.g., alternating Explore and Explain sequences before advancing to an Elaboration stage). Decisions of this kind will be determined and agreed upon by the development team during the *Development phase I-Curriculum Writer Content phase* of the production process. Word templates for each “E” in the learning cycle will be provided to the curriculum writer.

When creating a Science Object, the most difficult task for the development team will be to identify phenomena, simulations, interactions, and tasks that directly facilitate learning the Key Idea—without including extraneous information. It is crucial that the development team continually check to make sure that instruction serves the Key Idea and allows the learner to demonstrate his or her understanding as outlined in the “Evidences of Understanding” provided in the Scope Document. This “How To” Manual provides explanations, guidelines, and examples for each of the five stages of the learning cycle. Examples are available for review that

emphasize the importance of the alignment of each Science Object (and the entire SciPack) to the Key Ideas.

A note about language: Throughout the Science Object, all supporting text should be as concise and brief as possible. All text should avoid technical terminology whenever possible. While terminology can be essential for clear communication, it should not be used unless the learner understands the concepts and ideas behind the terminology.

Engagement

The introduction to a Science Object should engage the learner, arousing their curiosity, and set a direction for the learning experience. It should use real-world phenomena to hook the learner's interest. For example, you might challenge the learner with a scenario (such as a scientist exploring a perplexing problem), a series of questions that draw on familiar phenomena or a discrepant event that challenges intuition (but which can eventually be explained by scientific ideas). By the end of the Engagement stage, the learner should have a clear idea about the focus of the Science Object and what they will be doing.

The Engagement stage contains the following elements:

- Introduction
- Hook:
 - A challenging question or set of questions drawn from familiar real-world phenomenon.
 - A discrepant event that facilitates cognitive dissonance for learning.
 - An authentic scenario and a challenge they are trying to solve.
 - A simulation that may be revisited or scaled in complexity as a theme throughout the Science Object.
- Reflection

Engagement Guidelines

Follow the guidelines listed in the following table when building the content items for an Engagement stage. These guidelines will also be used to validate the quality of Science Objects as they are being built. A Word document template called “Engagement” will be used to capture your work and facilitate importing the content and image/simulation placeholders into the LCMS software. What follows is the reasoning for using a Word template for each “E” in the learning cycle.

ITEM	GUIDELINES
Introduction	<p>Establish the purpose of the Science Object and orient learners to what they are expected to learn, and how the instruction will proceed (e.g., “First we are going to look at some real-world phenomena, then we will move on to finding ways to explain those phenomena and predict what might happen in new situations.”)</p>
Hook	<p>Include piece of visual media to draw in learner on first page (may be compelling still or animated graphic, simple interactive simulation, or streaming RealMedia clip).</p> <p>The hook should include one of the following interaction types:</p> <ul style="list-style-type: none"> • Challenging question(s) drawn from real-world phenomena. • Discrepant event that facilitates cognitive dissonance. • Place learner in role as problem solver within an authentic scenario or challenge. • Simple simulation that may be revisited or increased in complexity throughout the Science Object. <p>Each interaction should:</p> <ul style="list-style-type: none"> • Create interest and curiosity. • Raise questions. • Help the learner recognize his/her background or prior knowledge of the topic.

Reflection	Inspire questions such as: Provide an explanation why this happened? What do I really know about this?
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Exploration

At this stage, the learner should be immersed in exploring real-world phenomena or events and making careful observations. The simulations and supporting questions/text must help the learners probe and clarify real-world phenomena that address the Key Idea for this science object. Exploration should be conscientiously designed to make the Key Idea plausible, so that the learner will be prepared to make use of and demonstrate understanding of the Key Idea in later stages. Adequate time for thorough investigation is critical.

The Exploration stage contains the following elements:

- Introduction
- Continuation or enhancement of the scenario, challenge, or simulation presented in the Engagement stage.
- Opportunities to clarify real-world phenomena and make careful observations that will support later inferences and ideas.
- Opportunities to try different settings, switches, locales, other themes and variations.
- Observation and data collection suggestions if applicable.
- Requesting learner predictions and/or initial explanations.

Exploration Guidelines

Follow the guidelines in the table when building the content items for the Exploration stage. These guidelines will also be used to validate the quality of Science Objects as they are being built. A Word document template called “Exploration” will be used to capture your work and facilitate importing the content and image/simulation placeholders into the LCMS software.

ITEM	GUIDELINES
Introduction	<p>Build on Engagement to encourage the learner to further explore and clarify the phenomenon, scenario, challenge, etc.</p> <p>Continue to help the learner understand the sequence of the learning experience and what will happen during this stage.</p>
Continuation of Scenario, Challenge, etc.	<p>Guide learner with questions to delve deeper into phenomenon, challenge, or scenario from Engagement.</p> <p>Provide increased scaffolding or context to phenomenon, without providing “the answers.”</p> <p>Use “Check Your Thinking” interactions to provide feedback as necessary.</p> <p>Encourage learners to pose their own questions, or reflect upon their own understanding/experiences of the phenomenon or challenge at hand.</p>
Simulation or Hands-On Activity	<p>Provide rich simulations, experiments, and/or demonstrations that can be controlled or “tweaked” by the learner, such as the information, variables, and/or conditions.</p> <p>Incorporate interaction and feedback using elements such as mouse-over, multiple-choice questions, or slideshow.</p>
Observations and/or Data Collection	<p>Ask the learner to make careful observations using the simulation, comparing and contrasting relationships that may surface.</p> <p>Guide learner to notice aspects of the simulation or phenomena that will support plausibility of the Key Idea.</p> <p>If possible, ask the learner to collect data (quantitative or qualitative) as they engage in the scenario or challenge.</p> <p>If possible, have the learner organize and display data in charts and graphs.</p> <p>Support the learner in recognizing and analyzing patterns or trends in the data.</p>
	<p>Encourage learners to make initial predictions about the outcomes prior to</p>

Predictions and Initial Explanations	<p>advancing through simulation/investigation if appropriate.</p> <p>Ask the learner to reflect upon their observations, interactions, and predictions and attempt an initial explanation for their observations.</p> <p>Incorporate interactive feedback.</p>
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Explanation

This is the place to reflect on stages of learning, moving from concrete to abstract, from the known to the new. In the Explanation stage, the learner should be guided to attempt to explain the challenges, scenarios, phenomena, etc. presented in the preceding stages.

(Eventually, the learner should also be guided to see how the Key Idea in the Science Object can be used to explain those things.) An understanding of common preconceptions is essential to the design of the learning experiences at this stage. The Exploration stage should present any appropriate common preconceptions as alternative explanations or distractors within multiple-choice questions, so that the learner can, through questioning and activities, be challenged, opening the learner to seeing the explanatory power of the Key Idea. One should avoid a declarative explanation of the preconceptions inherent in the Key Idea being facilitated.

The Explanation stage contains the following elements:

- Introduction
- Demonstrations and animations provided for clarification and opportunities to attempt explanations for challenges, phenomena, etc.
- Additional learner questions posed to address known preconceptions.
- Alternative explanations presented and explored.
- Challenges, questions, phenomena, etc. (focus on a particular aspect of the engagement and exploration experiences) explained using scientific ideas.
- Reflections on what has been learned and opportunities to confirm or represent that knowledge.

Explanation Guidelines

Follow the guidelines in the table when building the content items for an Explanation stage. These guidelines will also be used to validate the quality of Learning Objects as they are being built. A Word document template called “Explanation” will be used to capture your work and facilitate importing the content and image/simulation placeholders into the Evolution software.

ITEM	GUIDELINES
<p>Introduction</p>	<p>Revisit the explored scenarios and describe processes by asking questions such as “Did you notice this? Why do you think it happens? Is there an alternative explanation?”</p> <p>Again, make sure the learner understands the direction and purpose of this stage in the context of the entire learning experience.</p>
<p>Clarification and Initial Explanations</p>	<p>Present facts, observations, or situations that further clarify the phenomena, etc.</p> <p>Provide the learner with opportunity to come up with their own explanation of challenges, phenomena, etc. building on the initial explanations given in the last stage.</p>
<p>Addressing Alternative Explanations</p>	<p>Draw from literature to question the learner to explore common preconceptions.</p> <p>Present alternative explanations (also drawn from literature where possible) for the challenges, phenomena, etc.</p> <p>Present questions, facts, or observations that challenge alternative explanations.</p> <p>Guide the learner toward seeing how the Key Idea can provide an explanation for phenomena, questions, observations, etc.</p>

<p>Practice, Application</p>	<p>Look back at previous phenomena, observations, etc., with new insights and explanations in mind. Seek to include multiple-choice questions that address known misconceptions and incorporate distracters in the selection options to provide rich feedback and remediation when necessary.</p>
<p>Reflection</p>	<p>Provide the opportunity for the learner to present what they have learned through concept maps, written explanations, etc.</p>

Elaboration

All adult learners want to know that the material has some utility. This is the place to give learners a chance to use and apply what they have learned. The Elaboration stage should provide opportunities for the learner to explore the implications of the Key Idea in the Science Object in novel contexts and situations. Through these new experiences, the learner should develop deeper and broader understanding. At the beginning of this stage, it is helpful if learners verbalize what was learned and are permitted to apply the knowledge to what they already know. Then the learner can move toward applying the Key Idea in a different context or real world situation. The Elaboration stage should also help the learner connect the Key Idea to other scientific ideas and things they already know. If they can do this, they are more likely to truly understand and retain their new knowledge.

The Elaboration stage should contain the following elements:

- Introduction
- Chances to test new parameters on previously explored scenarios.
- Guidance in seeing how the Key Idea in the Science Object relates to other scientific ideas and other known facts.
- Extensions of learning experiences to apply the Key Idea in new contexts or under new conditions.
- Reflection and Summary

Elaboration Guidelines

Follow the guidelines in the table when building the content items for an Elaboration stage. These guidelines will also be used to validate the quality of Science Objects as they are being built. A Word document template called “Elaboration” will be used to capture your work and facilitate importing the content and image/simulation placeholders into the LCMS software.

ITEM	GUIDELINES
Introduction	<p>Build on Explanation stage to introduce the idea of using the Key Idea in new contexts to show its predictive and explanatory power.</p> <p>Continue to help the learner understand the sequence of the overall learning experience.</p>
Extension	<p>Case studies analysis.</p> <p>Simulation analysis.</p> <p>Provide a new scenario or phenomena related to the Key Idea in the Science Object and have the learner explain what happened or predict what would happen if the parameters were changed.</p> <p>Have the learner analyze a new challenge or case study and apply the principles learned to generate a solution.</p> <p>Have the learner determine where a simulation or representation fails to emulate a real-world situation and describe the pros and cons of the simulation.</p> <p>Evaluate between competing alternative explanations of a phenomena or solutions to a challenge that require application of the Key Idea.</p>
Summary	<p>Provide a summary of the extension for the learner and emphasize how the new scenario, simulation, challenge or case study is related to the previous experiences in this learning object. Facilitate application of the previous learning to the new elaboration being presented for analysis.</p>

Evaluation

The simulations throughout the Science Object should, through probing, help the learners evaluate their understanding at all stages. But, it is this final stage that will provide a complete assessment of the Key Idea for this Science Object. This is a formative assessment that will let the learner know if they are right or wrong in their answers, but this will not be assigned a summative grade for certification purposes.

This stage should include tasks that require the learner to use the Key Idea, thus demonstrating that they have obtained that idea. Also, the tasks should not demand extraneous knowledge (which might cause a learner who does have the Key Idea to respond incorrectly). The tasks in this section of the Science Object should allow the learner to answer the question, "What did I learn about the Key Idea and how well did I do in demonstrating that learning?" The LCMS can provide tailored feedback dependent upon which item is selected from an assessment question. Adult learners should be counted on to take more responsibility for monitoring their understanding. For example, the learner can match their response to a set of prepared sample responses, and feedback can be based on that match. It is important that the tasks developed for this stage measure a range of depth of understanding and be aligned with the Key Ideas and "Evidences of Understanding" identified in the Scope document. Correct use of technical terms, or rote performance of algorithms are not sufficient evidence of understanding.

The Evaluation stage should include the following elements:

- Simple competency questions
- Synthesis-encouraging reconstructions or information mapping
- Based on the original engaging scenarios and probe learner for understanding, application, synthesis, and/or evaluation (higher-order thinking skills).

Note: The LCMS Assessment Chapter provides examples depicting how to writer higher-order

assessment types with the features available within the LCMS. Please refer to that document before creating your questions. A final postassessment will assess a learner’s understanding of all the key ideas contained within the three to five science objects that make up an entire SciPack.

Evaluation Guidelines

Follow the guidelines in the table when building the content items for the Evaluation stage. These guidelines will also be used to validate the quality of Science Objects as they are being built. A Word document template called “Evaluation” will be used to capture your work and facilitate importing the content and image/simulation placeholders into the LCMS software.

ITEM	GUIDELINES
Introduction	<p>Let the learner know that this is a formative evaluation to help him or her assess his or her own level of understanding the Key Idea for this Science Object.</p> <p>Attempt to maintain the instructional context or challenge that was introduced at the beginning of the Science Object.</p>
Instructional Assessment Types	<p>Create four to seven total questions</p> <ul style="list-style-type: none"> • Multiple Choice (single/multiple answer) • Matching • Ordering (sequence) • Hotspot (sequence and unsequenced) • Drag and Drop • Fill in the Blank
Assessment Question Components	<p>Hints: Hints are provided to assist learner after reading stem of question. The learner may select a hint if desired before a choice is made from available</p>

	<p>options.</p> <p>Feedback: Customized feedback may be provided based on each selection from available choices. Feedback should provide additional insight for learner based on choice selected, and item “distractors” should be attempting to identify known misconception research.</p> <p>Remediation: If a learner exhausts the number of tries provided for a question and fails to select the correct answer, he or she may be provided a link back to the existing section of the science object that the assessment question is drawn from, and/or be presented with a link that directs the learner to additional content that is available for the first time.</p>
<p>Embedded Assessment Media (Optional)</p>	<p>The LCMS allows many types of media to be embedded within the question (gif, jpg, QuickTime, video, flash). Please refer to the LCMS Assessment chapter for additional guidelines on creating question types with embedded media.</p>

Appendix E:
Teacher Preference Survey

Thank you for taking the time to complete this survey. It will inform current online learning theory as well as future developers as to which online interaction strategies you find most valuable. District and state science administrators will also be informed when making professional development selection decisions for the teachers they support.

The survey is broken down into three parts:

- * Part 1: Demographic Information (4 questions)
- * Part 2: Teacher Learning Preferences (12 questions)
- * Part 3: Online Content Interaction Strategy Preferences (25 questions)

Please input the personal identification code provided to you in the invitation email to access this survey. This code ensures your anonymity throughout the study, but allows analysis of all data related to pre/post assessments and the information provided below.

IMPORTANT: If you do not have the code, please contact Al Byers at abyers@nsta.org, or call: 571-643-3360 and a unique code will be provided to you.

Input the personal identification code:

Part 1: DEMOGRAPHIC QUESTIONS

Below are four questions regarding key demographics that will be used for comparison across different educator groups. Thank you for answering these questions as it is key to the research.

1. Please provide your current age in years:
2. Please indicate the range of years experience you have as a professional educator (including this year).

Provide the total years teaching experience (in years):

3. Please check the grade level(s) you currently teach (check multiple grades if this applies):

- Grade 1
- Grade 2
- Grade 3
- Grade 4
- Grade 5
- Grade 6
- Grade 7
- Grade 8

4. Please select the teaching license description that best reflects your current teaching credentials:

- Elementary Education (preK–6)
- Middle Education (6–8)

Secondary Science—General
Secondary Science—Life Science
Secondary Science—Earth/Space Science
Secondary Science—Physical Science
Multiple Secondary Science Subject endorsements

Part 2: TEACHER LEARNING PREFERENCES

This section of questions describes the way you learn and how you deal with ideas and day-to-day situations in your life.

Below are 12 sentence groups with a choice of 4 endings for each sentence group. Rank the endings for each group according to how well you think each ending fits with how you would go about learning something. Try to recall some recent situations where you had to learn something new, perhaps in your job.

Rank your selection for the sentence ending that describes how you learn best. Be sure to rank all the endings for each group. Please do not make ties. Select a different letter for each ending within a group (rank order your preferences for that group).

Note: Permission to use the Kolb LSI 3.1 secured from the Hay Group. Copyright prohibits listing the instrument in this study. Contact Jessica L. Menendez, Hay Group, Transforming Learning, 116 Huntington Ave., Boston, MA 02116. Phone: 617-927-5026. Web: www.haygroup.com/TL

PART 3: ONLINE CONTENT INTERACTION STRATEGY PREFERENCES

Below each content description and example please answer the questions to the best of your ability, recalling your experience as you completed your particular web module in a particular science content area.

Learner Preference for Content Interaction Types
<p>Simulation: Employs high level of user control, where learners may change the parameters or values of variables within the simulation and see the resultant difference in observed phenomenon (e.g., height of object dropped, type of surface ball is rolling across, etc.). Appears within the SciPack content labeled as "click here to start interactive." In certain instances the "interactive" is more an animation that is viewed with the intent for observation of phenomenon for the science concept in question.</p> <p>Example from the Force and Motion Web Module:</p>

http://scipacks.nsta.org/?curID=00065BF1B6260A8F2C5501050000036&courseID=00065BF1B6260A8F2C730...

NSTA SciPacks Force and Motion Newton's Third Law 3 OF 8

Home Ask the Wizard Reset Page Previous Next

Newton's Third Law

- Introduction
- The Basic Idea
- A Full Statement
 - A Full Statement of the Third Law
 - Simulation**
 - What the Simulation Teaches Us
 - Applying the Third Law
 - A Couple of Common Misconceptions
 - What About Action-reaction?
- Applications and Summary
- Evaluation
- SciGuide
- Glossary
- Credits

Simulation

In the following simulation you have two carts that are sitting on an air track. An air track is a lot like the table used in air hockey. There are lots of tiny holes through which air blows. There are enough holes that the carts ride on a cushion of air. This results in a very tiny force of friction---so tiny that we can ignore it. When you push the start button, cart A releases a spring-loaded piston that exerts a force on cart B. You can vary the force that this piston exerts, and you can also vary the masses of the carts. Before you get too serious about the simulation, just hit the start button for any old combination of force and mass. Notice what happens. Then answer the following question.



Figure 3.2. Air Track Simulation
For those unable to engage with the interactive component, select this link for a long text description:
[Text Description](#)

NSTA SCIENCE SIMULATION: Air Track INSTRUCTIONS

Before You Begin

Air Track is a simulation of an actual piece of physical science lab equipment. Here you are presented with two carts and a limited number of choices, the mass of each cart and the force applied from cart A to cart B. Select one choice for each and run the experiment multiple times. You may use the magnification tool to see more or less of the whole air track.

Use the instructions tab to reveal the specific instructions to operate this interactive simulation.

CONTROL PANEL

<input type="checkbox"/> START	Piston Force	Cart A mass	Cart B mass
<input type="checkbox"/> STOP	X 1 N	X 1 kg	X 1 kg
<input type="checkbox"/> RESET	2 N	2 kg	2 kg

PROCEED

mag %

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

CONTROL PANEL

<input type="checkbox"/> START	Piston Force	Cart A Mass	Cart B Mass
<input type="checkbox"/> STOP	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> RESET	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg

air track magnifier 171 %

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

CONTROL PANEL

<input checked="" type="checkbox"/> START	Piston Force	Cart A Mass	Cart B Mass
<input type="checkbox"/> STOP	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> RESET	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg

air track magnifier 171 %

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

CONTROL PANEL

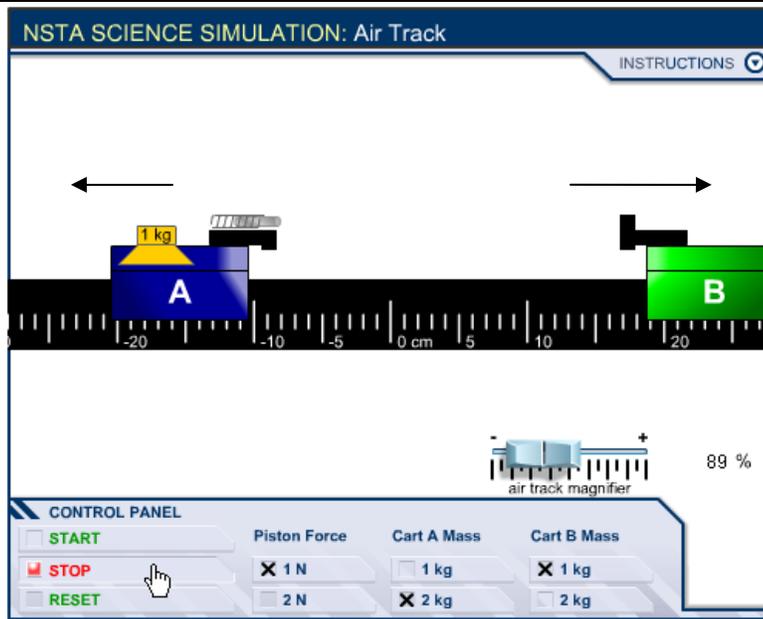
<input checked="" type="checkbox"/> START	Piston Force	Cart A Mass	Cart B Mass
<input checked="" type="checkbox"/> STOP	<input checked="" type="checkbox"/> 1 N	<input checked="" type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> RESET	<input type="checkbox"/> 2 N	<input type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg

NSTA SCIENCE SIMULATION: Air Track

INSTRUCTIONS

CONTROL PANEL

<input checked="" type="checkbox"/> START	Piston Force	Cart A Mass	Cart B Mass
<input checked="" type="checkbox"/> STOP	<input checked="" type="checkbox"/> 1 N	<input type="checkbox"/> 1 kg	<input checked="" type="checkbox"/> 1 kg
<input type="checkbox"/> RESET	<input type="checkbox"/> 2 N	<input checked="" type="checkbox"/> 2 kg	<input type="checkbox"/> 2 kg



<p>Please answer the questions below as honestly and thoughtfully as possible now that you have reviewed the content-interaction preference type above.</p> <p>Remember the purpose of this survey is to determine which online content types you perceive as most valuable in response to the questions below.</p>	Strongly Agree							Strongly Disagree
		7	6	5	4	3	2	1
1. I think this content type is engaging to me.								
2. I think this content type facilitates my learning science content.								
3. I think this content type helps my retention of the science content over time.								
4. I think this content type facilitates teaching the science content to my students.								
5. I would like to see more of this content type.								

Appendix F:
Kolb Learning Style Inventory 3.1 Research Permission

From: Jessica Menendez [<mailto:Jessica.Menendez@haygroup.com>]

Sent: Tue 9/15/2009 1:20 PM

To: Al Byers

Subject: FW: HRD Site Contact Form--Request for use of Kolb Inventory

Hi Al,

The committee has approved your proposal.. Also, the committee has answered your question below:

Interested in: How would you classify Kolb's learning style individual results along either CE, RO, AC, AE, and CE-AC and RO-AE? Are the results considered categorial for individual quadrant constructs (CE, RO, AC, & AE), and continuous for CE-AC and RO-AE?

Answer: These are all continuous values. The only categorical values are the learning style types: accommodating, diverging, converging, and assimilating.

If you have any further questions, you can e-mail Alice Kolb directly at aliceykolb@gmail.com.

Thank you,

Jessica L. Menendez

Hay Group Transforming Learning

116 Huntington Avenue

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Appendix G:

Overview NSTA Online Pre- and Postassessment Instrument

Developing Diagnostic Multiple-Choice Assessment Items for the
National Science Teachers Association's Online Professional
Development Indexer Tool

Al Byers
Assistant Executive Director
e-Learning and Government Partnerships
National Science Teachers Association

Susan Koba, Ph.D.
Science Education Consultant

Joan Schepke
Senior Director, e-Learning Production
National Science Teachers Association

Greg Sherman, Ph.D.
Instructional Design and Evaluation Consultant

Roger Bolus, Ph.D.
Research Solution Group

The National Science Teachers Association's (NSTA) online Learning Center represents a collection of web-based tools designed to help professional educators identify, access, manage and evaluate professional development resources and opportunities. Some of the tools available in the Learning Center include an advanced search form enabling teachers to easily locate NSTA resources such as journal articles, archived web seminar sessions, electronic copies of NSTA Press book chapters, and free self-directed web-based interactive content-specific learning opportunities called Science Objects and SciPacks. Science Objects are 2-hour online experiences that employ an inquiry-based design and incorporate interactive and embedded questions to facilitate teacher learning. SciPacks are 10 hours in duration and include three to five science objects, plus a glossary, pedagogical implications component, unlimited email help from a content expert, and an opportunity to complete a final assessment to document their content knowledge understanding. When a teacher identifies professional development resources of interest, access to these resources can be easily stored and organized into collections within the Learning Center's *My Library* tool. These resources can easily be shared with colleagues if desired. The Learning Center also provides teachers with tools that enable them to identify personal professional development goals, manage goal accomplishments, and communicate successful personal goal completions with others through the use of the *My Calendar* and *My Professional Development Plan and Portfolio* tools.

Most of the tools provided in the NSTA Learning Center are designed to help teachers locate, organize, and manage the use of NSTA professional development resources. But the Learning Center also provides a tool designed to help individual teachers identify possible areas of professional development need related to specific science content. The *My PD Indexer* tool

represents a diagnostic experience in which teachers can select general areas of science content and then answer questions related to their chosen topics. These multiple-choice assessment items reflect randomly drawn questions from a database populated by a number of well-designed questions aligned to specific content areas. Currently, the topics available in the PD Indexer represent many of the specific content areas addressed within Science Objects developed for the general content areas of Earth and Space Science, Life Science, and Physical Science.

The PD Indexer keeps track of individual results for each diagnostic assessment completed, and it recommends specific NSTA resources addressing the content of those items not answered correctly. These resources can be easily added to a teacher's online library, and specific professional development goals can be generated based on content deficiencies identified. Recommendations include such resources as journal articles, book chapters, web seminars, online short courses, and Science Objects. When the Learning Center is deployed through a district and state initiative, these items are used as a pre- and postassessment instrument to document gain in content knowledge after completing a SciPack. Teachers complete 15–25 items in a content area, such as Plate Tectonics and the results are saved for comparison to the posttest (same items) at a later point in time once the SciPack on the same content area has been completed.

Science Objects and SciPacks represent the most direct remediation to any identified content deficiencies because they have been developed to facilitate skills associated with the content addressed by the PD Indexer items. As more Science Objects are developed, additional PD Indexer items will be created and made available in the PD Indexer tool.

The purpose of this report is to document the procedures conducted by the developers of the latest round of PD Indexer items in an effort to communicate the rigor involved in the item

development process as well as inform the development process of future PD Indexer items.

This report summarizes all the procedures followed, and it includes pilot testing results as well as information about the people involved in the process. This report also includes copies of all the finalized assessment items for this round of development.

PD Indexer—Pre- and Postassessment Item Content Areas

The content areas addressed within this round of PD Indexer item development included the specific topics included in five different sets of Science Objects. These Science Objects comprise the content for the following SciPacks:

- Earth’s History
- Food Science Safety
- Magnetic and Electric Forces
- Nature of Light
- Resources and Human Impact
- Atomic Structure
- Chemical Reactions
- Elements, Atoms, and Molecules
- Nutrition
- Cell Division and Differentiation
- Cells and Chemical Reactions

Each SciPack listed contains three or four Science Objects. At the time the PD Indexer items were to be developed, each SciPack was in a different stage of development. The outcomes or “evidences of understanding” for all SciPacks were well defined, but some of the actual

content for some Science Objects was not completely developed. A sample of the evidences of understanding for one of the SciPacks (Earth's History) is presented below.

Science Object 1: *Biography of Earth*

- EH1.1 Describe the key events in the early history of Earth's formation and the relative times of their occurrence in Earth's history.
- EH1.2 Explain scientists' estimation of the age of rocks at Earth's surface by referring to evidence.
- EH1.3 Explain scientists' estimation of the age of Earth by referring to evidence.
- EH1.4 Describe the limitations of radioactive dating methods.
- EH1.5 Compare the physical principles and particular processes at work in Earth's history and today that are significant to determine the age of Earth.
- EH1.6 Differentiate between the observations (evidence) and inferences that scientists use in establishing the age of Earth.

Science Object 2: *A Date With Fossils*

- EH2.1 Describe how scientists mark major eras in Earth's history.
- EH2.2 Distinguish between life before and after the Cambrian.
- EH2.3 Provide a rough estimate of how long ago life first appeared on Earth. Use evidence to defend this estimate.
- EH2.4 Compare the principles and life processes at work in Earth's history and today that are significant to developing a geologic timeline.
- EH2.5 Explain the role, and limitations, of the fossil record in establishing a geological timeline.
- EH2.6 Give several examples of how life, or the development of life, has produced a change in Earth's land, air, and water.

Science Object 3: *Key Earth Systems Interactions*

- EH3.1 Describe the major processes that affect the evolution of the Earth system.
- EH3.2 Describe how different parts of the Earth system, such as the land masses, oceans, atmosphere, and life forms, have influenced one another in the past.
- EH3.3 Describe how the major variables (such as volcanic eruptions, catastrophic impacts, atmospheric and ocean composition, etc.) have influenced Earth's systems at any

particular time.

EH3.4 Interpret data given to support claims about past climates.

So for labeling of all test items for analysis, the designation of a sample test item EH1.4.1 would correspond above to Key Idea #1, Evidence of Understanding #4, and Item #1. If there were four items developed for this evidence of understanding, they would be coded EH1.4.1, EH1.4.2, EH1.4.3 and EH1.4.4.

The overall goal of this round of PD Indexer item development was to generate approximately 5 well-designed, effective items for each science object, resulting in final test sets for each SciPack between 15 and 25 items.

The PD Indexer Item Development Process Overview

The overall process for developing indexer items for the five target SciPacks involves the following stages and steps, which are summarized below and expanded upon in more detail following these summaries. Four discrete stages and the respective substeps ensured items developed were both valid and reliable:

Stage 1: Item Development

Step 1—Identify and train item developers.

Step 2—Item developers generate items based on SciPack evidences of understanding.

Step 3—Items submitted to subject matter experts.

Step 4—Items edited by assessment expert.

Stage 2: Pilot Testing

Step 5—Prepare items for online pilot testing and recruit pilot testers.

Step 6—Collect pilot data and analyze pilot results.

Stage 3: Final Item Selection

Step 7—Item reviewers evaluate pilot data (two reviewers per set).

Step 8—Item review team evaluates items for bias and content alignment with stated evidences of understanding.

Step 9—Select final items based on item reviewer recommendations.

Step 10—Test-level analysis on selected items conducted.

Stage 4: Final Item Preparation

Step 11—Clean up graphics and edit copy.

PD Indexer—Pre- and Postassessment Item Content Areas

The content areas addressed within the latest round of NSTA PD Indexer item development included the specific topics included in 11 different sets of Science Objects. These Science Objects comprise the content for the following SciPacks:

- Earth's History
- Food Science Safety
- Magnetic and Electric Forces
- Nature of Light
- Resources and Human Impact
- Atomic Structure
- Chemical Reactions
- Elements, Atoms, and Molecules
- Nutrition

- Cell Division and Differentiation
- Cells and Chemical Reactions

Each SciPack listed contains three or four Science Objects. The outcomes or “evidences of understanding” for all SciPacks were well defined, and a portion of the content for the Science Objects was completed. The components for one of the SciPacks (Earth’s History) and a sample of the respective evidences of understanding are presented in Figure 1.

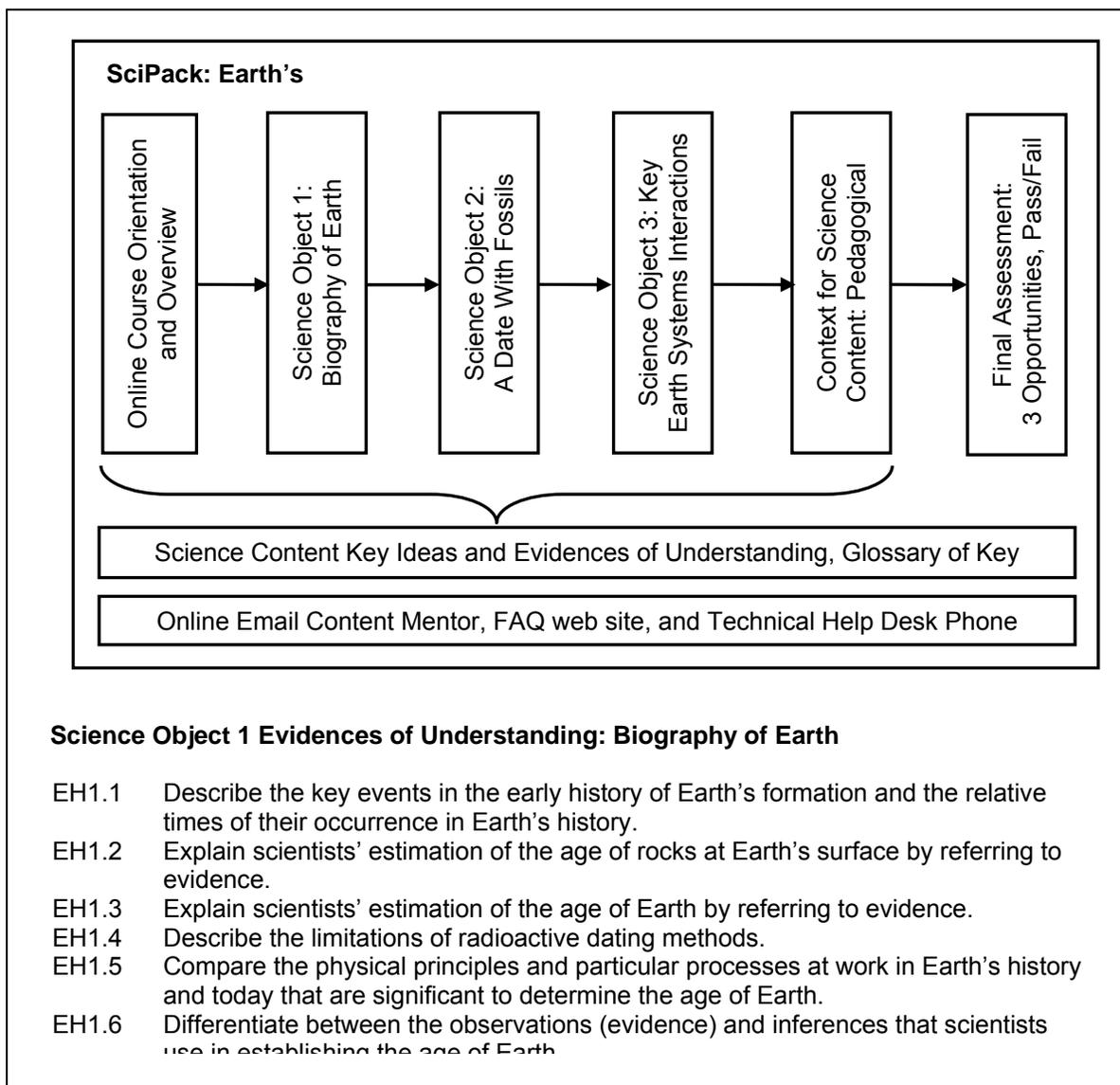


Figure 1. SciPack Components and Evidences of Understanding for one Science Object

The overall goal of this round of PD Indexer item development was to generate enough items to ensure at least five well-designed, effective items for each science object that could be selected, resulting in final test sets for each SciPack, ultimately resulting in generating between 15 and 25 items for each SciPack.

Stage 1: Develop Draft Items

Item developers were selected by members of the NSTA PD Indexer team, based on their previous work with NSTA, their demonstrated grasp of the content knowledge, and in some cases their previously identified status as master teachers. For the topic of Food Science Safety a recently retired master biology teacher with experience in item development for WestEd was secured. A retired master teacher in physics, with experience in national curriculum development generated draft items for Atomic Structure and Magnetic and Electric Forces content areas. Several retired district and state science administrators with PhD's and national board certification assisted in generating draft items for the science topics in biology and resources and human impact. See Table 1 for listing of example item developer team members.

Table 1
Item Development Team Members

Developer	Background	Content
Jason Krumholz	Jason Krumholz is currently a PhD candidate in biological oceanography from the University of Rhode Island. His research interests include estuarine ecology, and ecology of marine protected areas.	Earth History
Charlie Watt	Mr. Watt, a master biology teacher, recently retired from the Omaha Public Schools. He has previous history with item development in the school district and for WestEd.	Food Science Safety
Patty Rourke	Ms. Rourke is a retired master teacher of physics with additional expertise in chemistry. She worked extensively with the Jason Project and in the development of Active Physical Science.	Magnetic and Electric Forces Atomic Structure Chemical Reactions

Katya Denisova	Dr. Denisova is a master physics teacher from Baltimore, Maryland. She has both her PhD and National Board Certification.	Nature of Light Elements, Atoms and Molecules
Elizabeth Mulkerrin	Ms. Mulkerrin taught with the Omaha Public Schools for 10 years before becoming the Educational Curator at the renowned Omaha Henry Doorly Zoo. She is currently working toward her PhD.	Resources and Human Impact
Deborah Tucker	Deborah Tucker, EdD, is a science education consultant. Her research interests include effective professional development strategies for both inservice and preservice teachers of science.	Nutrition Cell Division and Differentiation Cells and Chemical Reactions

Before the initial sets of items were developed, all item developers participated in a training session facilitated by an assessment expert. This session was designed to help the developers create valid multiple-choice assessment items within the parameters of the web-based pilot-testing environment. Strategies for creating and referencing graphics within the items were discussed, and the mechanisms for submitting items and revisions using web-based tools were demonstrated. Additionally, the item developers were provided with documents that detailed the evidences of understanding as well as background information associated with the content addressed within their assigned SciPack topic. Access to the material developed for the actual SciPack was provided if it was already developed.

The item developers created items for each Science Object based on their respective evidences of understanding and submitted them to the PD Indexer team upon completion. Once an initial set of items was developed, it was submitted to a subject matter expert for content review. The reviewers were experts in their respective fields with PhD's in the appropriate science content area under review. For example, a professor with a PhD in biology reviewed assessment items for the topic cell division and differentiation, and a university professor with a PhD in physics reviewed items for the topic nature of light. SciPack content areas are presented below in Table 2.

Based on the feedback of subject matter experts, individual items were edited by either the item developer or members of the PD Indexer team. In some cases, items were discarded if they were too similar to existing, usable items or, in rare cases, if they were too difficult to repair without completely rewriting the entire item. At this stage, items were also reviewed by the project assessment expert to ensure they conformed to guidelines reflecting valid and reliable multiple-choice assessment item development. These criteria were based on a number of assessment design models (Bashaw, 1991; Dick, et al., 2008; Gagne & Driscoll, 1988; Merrill & Tennyson, 1994; Popham, 2008; Sullivan & Higgins, 1983) and included the following multiple-choice assessment design strategies:

- Clear, concise, simple directions free of complex syntax or difficult vocabulary.
- Items must clearly elicit performances articulated within the Evidences of Understanding or objectives.
- Items are free of prompts or cues that could be used to determine the correct answer.
- No choices (distractors) are obviously incorrect.
- Words such as *a*, *an*, *he*, *she*, or plural words are not used to cue learners toward the correct answer.
- “All of the Above” cannot be used as a distractor.
- Words like “All” or “Never” are not used in the answer options.
- Words from the question are not repeated in the answer options.
- Negative answer options are not used following a negative question or stem.
- The use of negative statements in general is minimized.
- If negative statements are used, clear attention is drawn to words such as **NOT** (bolded, all caps).

- All distracters are generally the same length.
- Present a definite, explicit, and singular question or problem in the stem.
- Stems are stated as direct questions rather than incomplete statements.
- Words that might otherwise be repeated in each alternative are included in the stem.
- All distracters are grammatically parallel with each other and consistent with the stem.
- All distracters are mutually exclusive.

Table 2

Subject Matter Experts

Content	Subject Matter Expert	Background
Earth History	Francesca Casella	Dr. Casella has a PhD in environmental science and is a science education consultant.
Food Science Safety	Ann Alexander	Dr. Alexander is a professor in the department of food and nutrition at Radford University (Virginia).
Magnetic and Electric Forces	Jeff Lockwood	Dr. Lockwood has taught high school science for 28 years and is currently a science curriculum developer for TERC in Cambridge, Massachusetts.
Nature of Light	Brett Taylor	Dr. Taylor is a professor of physics at Radford University (Virginia).
Resources and Human Impact Cell Division and Differentiation Cells and Chemical Reactions	Bob Sheehy	Dr. Sheehy is a professor of biology at Radford University (Virginia).
Nutrition	Charlene Wolf-Hall	Dr. Wolf-Hall is an associate professor at the Great Plains Institute of Food Safety, North Dakota State University.

Stage 2: Pilot Tests

Once the set of assessment items for each topic was developed and edited (approximately three times the target number of assessment items), the items were entered into NSTA's online assessment system for pilot testing. Pilot testers were recruited from NSTA membership. In order to reach the SciPack target audience of middle school teachers, email contacts were selected from NSTA's database of members who subscribe to the NSTA middle school journal *Science Scope*. The testing was scheduled to be open for 1 week or until the target of 100 pilot testers for each topic was reached. After 100 pilot testers completed a test, it was closed for further participation. If the target number of pilot tests were not completed within 3 days, the same email was sent to additional *Science Scope* subscribers. In most cases, the target number of testers was reached within 3 days of the initial email.

When the pilot testing was completed, the data were exported, formatted, and sent to a psychometrician for independent item analysis. The statistics generated in the item analysis for one of the actual items is presented in Table 4. The objective of the initial item analysis was to identify items that would be clear candidates for the final version of each test based on reliability measures, (determine items that might require some modification, and eliminate items that did not measure their targeted outcomes within acceptable parameters of statistical reliability.

Table 4
Sample Statistical Analysis Results for Single Pilot Test Item

Item 3: * is keyed	1*	2	3	4
Responses	82.0%	4.5%	8.1%	5.4%
Upper 33%	91.9%	0.0%	2.7%	5.4%
Lower 33%	73.5%	8.8%	8.8%	8.8%
Item-Total: Point Biserial	0.259	-0.243	-0.077	-0.125
Item-Remainder: Point Biserial	0.207	-0.221	-0.042	-0.098

For each item, a response distractor analysis is first provided. This analysis reports the percentage of respondents selecting each choice. It further breaks down these percentages by the top and bottom one-third performing group (based on overall test score). The correct response for each item is marked with an asterisk (*) and responses 2–4 are the additional distractors. The purpose of this analysis is to document the degree to which test-takers are being drawn to each of the distractors (i.e., incorrect choices). Low percentages of respondents selecting certain distractors might be indicative of a weak distractor. If a large percentage of respondents from the upper third performing group (e.g., “high ability” participants) selected the same incorrect distractor, the statement was carefully examined to determine whether it could, in fact, be correct, or whether the wording of the distractor made it too plausible. The percentage of responses for the keyed-correct choice represents the item’s difficulty level. The analysis illustrated in Table 4 indicates a correct response rate of 82%, which (depending upon the skill measured by the item) may result in its exclusion from the final assessment set.

The next set of statistics presented in Table 4 illustrates the item’s discriminating power (i.e., the ability of the item to accurately differentiate more knowledgeable respondents from less knowledgeable respondents). Point biserial correlations were calculated for each item,

representing the average relationship between the participants' performances on a single item (correct or incorrect) versus how well they performed on the entire test. Like most correlations, this calculation is reported as a coefficient between -1 (a perfect negative relationship) and +1 (a perfect positive relationship). A positive coefficient implies that respondents who selected a specific distractor scored higher on the overall test, while a negative coefficient implies the opposite. Note that the point biserial statistics are provided for the "Item-Total" and "Item-Remainder." In the current setting, the latter presents a more accurate picture as it evaluates the relationship of the item with a total score *removing the effect of the item under examination*.

For diagnostic purposes, these statistics are provided for each choice. In examining the efficacy of each item, it was desirable to obtain positive point-biserials correlations greater than .20 (Nunnally, 1967) for the choice keyed correct while seeing negative or null point biserial correlations for the distractors. According to Crocker and Algina (1986), causes for these aberrant response patterns included:

1. No correct answers to an item
2. Multiple correct answers to an item
3. The item was written in such a way that "high ability" persons read more into the item than was intended and thus chose an unintended distractor while "low ability" people were not distracted by a subtlety in the item and answered it as intended
4. The item really had nothing to do with the topic being tested
5. A wrong answer was mistakenly keyed as the correct one on the scoring key

Items following an aberrant point-biserial pattern were subject to modification or elimination. An example summary of the item difficulty levels and item-remainder point-biserials for the science content topic of Earth's History items are included in Table 5.

Table 5
 Earth History Summary of Item Statistics Sorted by Item Remainder Biserial

Item Number	Item Name	Percent Correct	Item Remainder Biserial
5	EH1.2.3	72.1	-0.11
53	EHX08	16.2	-0.02
1	EH1.1.1	38.7	0.02
21	EH2.3.1	38.7	0.03
33	EH2.6.3	64.0	0.04
7	EH1.3.2	32.4	0.09
9	EH1.4.2	45.9	0.10
47	EHX02	65.8	0.11
25	EH2.4.1	62.2	0.13
18	EH2.5.2	71.2	0.14
16	EH1.6.2	38.7	0.16
31	EH2.4.2	69.4	0.16
38	EH3.2.2	82.9	0.16
50	EHX05	13.5	0.17
10	EH1.4.3	26.1	0.19
37	EH3.2.1	62.2	0.19
56	EHX11	69.4	0.19
4	EH1.2.2	64.0	0.24
13	EH1.5.2	26.1	0.24
36	EH3.1.2	77.5	0.24
45	EH3.4.3	44.1	0.24
6	EH1.3.1	55.0	0.25
51	EHX06	31.5	0.28
26	EH2.2.1	45.9	0.29
3	EH1.2.1	82.0	0.30
19	EH2.5.3	43.2	0.30
14	EH1.5.4	34.2	0.31
40	EH3.2.4	36.9	0.31
46	EHX01	81.1	0.31
49	EHX04	27.0	0.31
42	EH3.3.2	60.4	0.32

Item Number	Item Name	Percent Correct	Item Remainder Biserial
2	EH1.1.2	91.9	0.34
28	EH2.2.3	29.7	0.34
11	EH1.4.4	64.0	0.36
15	EH1.6.1	82.9	0.36
29	EH2.2.4	68.5	0.36
39	EH3.2.3	63.1	0.36
17	EH2.5.1	47.7	0.37
8	EH1.4.1	58.6	0.38
43	EH3.4.1	82.0	0.39
23	EH2.3.3	47.7	0.40
41	EH3.3.1	79.3	0.40
54	EHX09	79.3	0.40
44	EH3.4.2	78.4	0.41
12	EH1.5.1	60.4	0.44
20	EH2.1.1	39.6	0.44
34	EH2.1.3	47.7	0.45
55	EHX10	67.6	0.45
24	EH2.6.2	21.6	0.50
32	EH2.5.4	54.1	0.51
35	EH3.1.1	74.8	0.51
30	EH2.1.2	86.5	0.52
52	EHX07	64.0	0.52
22	EH2.3.2	34.2	0.55
48	EHX03	98.2	0.55
27	EH2.2.2	80.2	0.61

Stage 3: Select Final Items

After all the analyses were conducted for the pilot test items, the results were submitted to the item review team members. Brief profiles of these consultants are presented below in Table 6. The reviewers used these data to determine item quality. They also analyzed each item for bias, after being trained in bias analysis.

Table 6
Item Reviewer Team Members

Member	Background
Wanda Clarke, EdD	Retired from the Omaha Public Schools, most recently served the district as the Instructional Research Administrator. She was primarily responsible for training related to and development of the district’s Criterion Referenced Tests. Wanda served as an item reviewer during the first face-to-face phase of the Indexer development effort and now served on the Virtual Review Team, reviewing items for both Resources and Human Impact and Food Science Safety.
Timothy Cooney, PhD	Professor of Earth Science and Science Education at the University of Northern Iowa. Tim has been involved as a reviewer since the beginning of the Indexer development effort, serving on both face-to-face review teams and now on the Virtual Review Team. He reviewed items for Earth’s History as well as Magnetic and Electric Forces.
Katylee Hoover	Senior Researcher at Westat in the Division of Education Research. Katylee began reviewing Indexer items during the second face-to-face phase of item review. She also served on this Virtual Review Team, reviewing items for both Resources and Human Impact and Food Science Safety.
Joseph McInerney	Senior Researcher at Westat, working in Educational Studies. He began as an item reviewer for the Indexer development effort during the second face-to-face phase of work. He reviewed items for Earth’s History, as well as Nature of Light.
David White	Director of Standards and Assessment for Vermont Department of Education. David has served as an item reviewer since the beginning of the Indexer development effort, serving on both face-to-face review teams and now on the Virtual Review Team. During the virtual process, he reviewed items for Magnetic and Electric Forces, as well as Nature of Light.

The bias training for reviewers was developed using work by the Educational Testing Service (*ETS fairness review guidelines* 2003). Bias was evaluated according to the categories detailed by Hambleton and Rodgers (2004): content, language, structure, formatting fairness, and stereotyping. Finally, review team members evaluated the degree to which each item appeared to align with the stated evidence of understanding. Although this was previously addressed by the item developers in consultation with an assessment expert, multiple items addressing specific evidences of understanding could be ranked by the review team relative to their general ability to

measure the stated performances. After all the analyses were conducted for the pilot test items, the results were submitted to the item reviewer team members. The backgrounds of the item reviewers are selected for their experience in the appropriate subject matter areas and assessment item development. The panel includes expertise in both content and assessment. For instance, a university faculty in subject area in question (e.g., PhD professor of Earth Science at the University of Northern Iowa) reviews with a senior researcher from major education institutions and organizations (e.g., Westat, and Department of Education State Science Assessment Directors). The reviewers analyzed each item for bias as well as the degree to which each item appeared to align with the stated evidence of understanding. The criteria used to evaluate alignment as well as bias are included immediately below.

Item Alignment Criteria

- What is the intent of the *Evidence of Understanding*?
- To what degree does the item match this intent?
- Criteria to qualify match:

Level	Criteria	Recommended Action
3	Item completely meets the intent.	Keep.
2	Item meets most of the intent.	Revise part needed to match.
1	Item partially meets the intent	Completely revise or eliminate.
0	Item does not meet the intent.	Eliminate.

Next a content alignment review occurred, with two item reviewers evaluating each set of items. Reviewers worked individually reviewing items for degree of match, recording responses on an Item Content Alignment Form. For example, the reviewers for assessment items developed for the Magnetic and Electric Forces suggested improvements such as more accurate representations for illustrations, replacing distractors if a significant percentage of low scoring respondents selected a distractor, or increasing the length for certain distractors to equalize

length. After reviewing items individually, reviewers discussed ratings as a group, came to a consensus on a score for each item, and the team leader recorded the final scores on a new form.

All summary sheets presenting the alignment scores, bias feedback, point biserial data, recommendations, and general comments from each of the item were aggregated for analysis. The summary sheet assisted in identification of items that might be selected and/or targeted for modification and provided the item number (as it appears in the preceding distractor analysis), the item label, the item difficulty (% correct), and the discrimination index (item remainder biserial). For each test, there were three different sort orders for these statistics: by item number, by item difficulty, and by item discrimination to assist the reviewers in their selection and modification recommendations for items. Table 7 provides a sample of this review sheet that assisted in identification of items that might be selected and/or targeted for modification.

Table 7
Summary Page Earth History SciPacks: Reviewer Joseph McInerney

Item	Evidence Assessed	Alignment Score	Bias Yes/No	Data Quality Point Biserial	Recommendation (Include/Modify)	Comments (As needed)
1	EH1.2.1	3	No	.30	Include	Could be a tad easy at 82% correct.
2	EH1.2.2	3	No	.24	Include	
3	EH1.3.1	3	No	.25	Include	
4	EH1.4.1	3	No	.38	Include	
5	EH1.4.4	3	No	.36	Include	The question is much clearer than 1.4.3.
6	EH1.5.1	3	No	.44	Include	
7	EH1.6.1	3	No	.36	Include	Clearer than its companion 1.6.2.
8	EH2.5.3	3	No	.30	Include	Spelling: "EXEPT" should be changed to EXCEPT.
9	EH2.2.1	3	No	.44	Include	
10	EH2.3.3	3	No	.40	Include	Distractor 1, or option B, needs a time frame: 6000 what?
11	EH2.2.1	3	No	.29	Include	
12	EH2.2.2	3	No	.61	Include	
13	EH2.2.4	3	No	.36	Include	
14	EH2.2.2	3	No	.52	Include	
15	EH2.5.4	3	No	.51	Include	

16	EH2.1.3	3	No	.45	Include	An excellent question.
17	EH3.1.1	3	No	.51	Include	
18	EH3.1.2	3	No	.24	Include but modify	Use parallel wording for A, C, and D.: "area covered by shallow seas" and not "the amount of shallow seas."
19	EH3.2.1	3	No	.19	Include	The point biserial is borderline at .19, but the percent correct is solid at 62%. Spelling: "EXEPT" should be changed to EXCEPT.
20	EH3.2.3	3	No	.36	Include	
21	EH3.3.1	3	No	.40	Include	
22	EH3.3.2	3	No	.32	Include	The wording is a bit intricate but the question works.
23	EH3.4.1	3	No	.39	Include	Complex answer option structure but OK; good percent correct at 82%.
24	EH3.4.2	3	No	.41	Include	
25						I could not find a 25 th question I liked.

These reviews were then assessed by members of the PD Indexer team, and decisions were made regarding the selection of items to be included in the PD Indexer. In most cases, if items were recommended by both reviewers, they were included in the final set. If there was a discrepancy (i.e. recommended by one reviewer but not by the other), notes on the items were evaluated to determine if a simple edit might address concerns.

Once the final sets of items for all 11 SciPacks were identified, test-level statistical analyses were conducted on the pilot test results for the selected items. The data in Table 8 present the number of items selected for each set, the number of pilot test results for each test, mean and standard deviation, median and quartile scores, and Cronbach α internal consistency correlation statistics for all existing SciPack items.

Table 8
Test-Level Statistical Analysis Results

<i>Test</i>	No. of Items	No. of Cases	Mean	Std Deviation	1st Qrtile	Median	3rd Qrtile	Internal Consistency*
Earth History	20	111	62.3	18.2	50	60	75	.704
Food Science Safety	22	102	61.7	19.1	45	62	77	.787

<i>Test</i>	No. of Items	No. of Cases	Mean	Std Deviation	1st Qrtile	Median	3rd Qrtile	Internal Consistency*
Magnetic and Electric Forces	22	114	56.1	21.9	36	55	73	.821
Nature of Light	20	105	55.6	19.7	40	55	70	.737
Resources and Human Impact	16	100	79.0	15.2	69	81	91	.656
Atomic Structure	16	102	65.9	27.0	50	75	88	.882
Cell Structure and Function	23	261	13.2	14.7	12	13	15	.636
Chemical Reactions	23	101	60.5	24.6	39	61	83	.877
Elements, Atoms, and Molecules	28	103	83.3	14.3	75	86	93	.812
Nutrition	20	97	67.5	14.9	60	70	75	.609
Cell Division and Differentiation	22	97	69.1	17.4	59	73	82	.752
Cells and Chemical Reactions	24	94	59.4	20.1	46	58	75	.821
Force & Motion	25	220	60.6	19.1	48	60	72	.816
Energy	20	227	69.2	18.3	55	70	85	.759
Solar System	20	238	71.0	16.1	65	75	85	.695
Gravity and Orbits	17	254	71.0	23.0	56	78	89	.853
Universe	19	238	65.7	16.9	53	68	79	.669
Earth-Sun-Moon	18	220	73.0	17.2	61	74	87	.763
Rock Cycle	20	218	71.2	18.7	60	75	85	.772
Plate Tectonics	20	216	77.8	17.9	70	85	90	.790
Earth's Changing Surface	18	217	70.3	16.1	61	72	83	.696
Coral Reef Ecosystems	21	237	78.3	15.3	67	81	90	.738

* Chronbach α

Based on the data presented in *Table 8*, the PD Indexer development team approved the final set of items. There was some concern that the Resources and Human Impact test results indicated an assessment that was not adequately discriminating, with a mean score of 79% and a lower reliability score (.656). However, the evidences of understanding measured by the selected items generally addressed lower cognitive ability, and the items did align well with these evidences. The same argument is posited for Nutrition and Cell Structure and Function. Given these items based on the national standards (National Commission on Teaching and America's Future, 1996), which provide a basis for the floor, not ceiling of what all high school students should know upon graduation, these assessments are in line with the level of reliability for the purpose these items serve.

Stage 4: Final Item Preparation

Before the items were placed into the online PD Indexer system, the text of the items was sent to an editor, and the graphics for those items requiring them were sent to a graphic designer to ensure that they were clear and easily decipherable. Once this is completed the items are then reviewed by the Senior Director of e-Learning Production and in coordination with the Senior Director of the NSTA Learning Center and technology staff, the items are placed in the online tool available for use either to voluntarily diagnose their content need or as a pre- and postassessment depending on the nature of the use for the items. When used within the PD indexer to diagnose teachers' content knowledge, correct answers and scores are not reported for the end user, and only a smaller subset of the 20- to 15-item bank is available. When the items are used as a pre- and postassessment instrument, the entire bank of items in a content area is presented for the learner. Table 9 below provides sample items for Magnetic and Electric Forces,

which collectively reported a Chronbach α internal consistency reliability of .821 in Table 8 above.

Summary

NSTA has expended significant effort to ensure that the items used for the pre- and postassessment tool are internally valid and reliable, thus providing administrators insight into the growth teachers experience as they work through the self-directed e-PD resources that are part of their local strategic PD efforts. Caution should be given to attributing learning growth solely to web-based SciPacks if the learners are not randomly assigned to treatments in an experimental design. Although with a nonrandomized quasi-experimental model that uses intact nonrandomized groups with a control comparison group, pre- and postassessment is a viable method for analysis and consideration.

Item 1 ID

MEF1.1.2

Question

Docents at science museums often invite a student with long hair to step up to the podium and participate in a demonstration on static electricity. With all safety measures in place, the student is asked to place two hands on the ball of a Van de Graff generator.



The student's individual hair strands collect the same charge, and the hair splays out from the head as depicted in the photograph. Which of the following statements best explains what causes this person's hair to stand on end?

Correct Answer

The individual hair strands are all the same charge, so they repel each other.

Distractor 1

The hair strands stand up so that they can transmit the electrons from the generator to the air.

Distractor 2

Hair strands are forced up because of the repulsion of the opposite charge collecting at the feet of the student.

Distractor 3

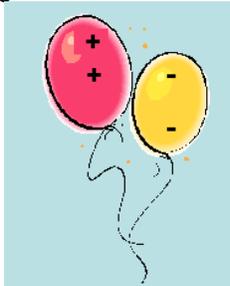
Hair strands repel each other because of the energy of the neutrons flowing through the Van de Graff generator to the student.

Item 2 ID

MEF1.2.6

Question

Suppose you rub two balloons with different materials, producing one balloon with a net positive charge, and one balloon with a net negative charge. Which of the following best describes what you might observe if the two balloons were brought in contact with one another?



Correct Answer

The negative charge redistributes itself evenly over the surfaces of both balloons.

Distractor 1

One positive charge moves from the red balloon to the yellow balloon.

Distractor 2

Positive charge redistributes itself evenly over the surfaces of both balloons.

Distractor 3

Negative charge moves from the yellow balloon to the red balloon to make the red balloon negative and the yellow balloon positive.

Item 3 ID

1.2.7

Question

Students can study static charges through a simulation of air table hockey. Two pucks are placed carefully near each other on the table. One puck has a static charge; one puck is neutral. Which of the following best describes what will most likely happen to the pucks?

Correct Answer

They will move toward each other because an attractive electrostatic force will be induced, drawing them toward each other.

Distractor 1

They will remain stationary because an electrostatic force does not exist since one puck is neutral.

Distractor 2

They might move toward each other or away from each other, depending on whether the charged puck is negatively or positively charged.

Distractor 3

They will move away from each other because a repulsive electrostatic force exists between them.

Item 4 ID

MEF1.3.2

Question



Water is a polar molecule because:

Correct Answer

Its three atoms share electrons unequally.

Distractor 1

Its three atoms are aligned in a row with the hydrogen atoms at one end and the oxygen atom at the other.

Distractor 2

A charged rod repels a stream of water.

Distractor 3

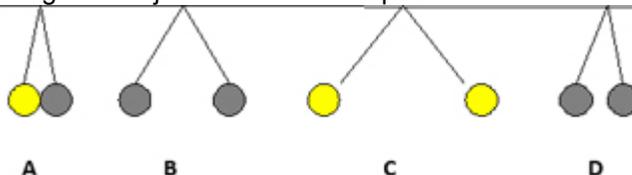
The lengths of the hydrogen bonds vary among the molecules of water.

Item 5 ID

MEF1.4.1

Question

Each object in the diagram is given a static charge and then attached to a string. The objects move and suspend themselves as arrayed in the diagram.



Examine the sets of charges depicted in the diagram. Different colors represent different charge polarities. From the information given, you may say that:

Correct Answer

The static charge on Set C Objects is the greatest.

Distractor 1

The static charge on Set A Objects is the same.

Distractor 2

The static charge on each object in Set B differs from one another.

Distractor 3

The static charge on Set D is greater than that on Set B.

Item 6 ID

MEF1.4.2

Question

Students can study static charges through a simulation of air table hockey. The centers of three pucks are carefully placed on the pattern of an isosceles triangle with sides of 12 cm. The pucks do not touch each other but they slowly move along straight lines directly out from each of the triangle vertices. This indicates that:

Correct Answer

The electrostatic force experienced by each puck is the same.

Distractor 1

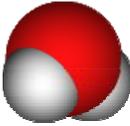
Two of the pucks exhibit a positive charge and one puck has a negative charge.

Distractor 2

Two of the pucks share a negative charge and one puck has a positive charge.

Distractor 3

Each puck repulses one of the other pucks and attracts the third puck.

Item7 ID	MEF1.4.5
Question	Coulomb's law says that the force exerted by charged objects on each other changes as the inverse square of the distance between them. This means that if the distance between two objects with the same charge is twice as great, the force of repulsion is:
Correct Answer	One fourth of the original force
Distractor 1	Four times the original force
Distractor 2	One half of the original force
Distractor 3	Two times the original force
Item 8 ID	1.5.3
Question	
	A water molecule has special properties that make it a polar particle. This means that:
Correct Answer	The shape of the molecule creates one side that is more negative than the other side of the molecule.
Distractor 1	Two water molecules repel each other to make water into a flowing material.
Distractor 2	When two water molecules are next to each other, they attract each other by their more electropositive ends.
Distractor 3	As water molecules move closer to each other, hydrogen bonds are formed that are unique to polar molecules.
Item 9 ID	MEF2.2.1
Question	Which of the following characteristics would describe a material that would probably make a good electrical conductor?
Correct Answer	A material that possesses loosely-bound electrons able to move through a conductor.
Distractor 1	A material that has tightly bound electrons, facilitating the movement of charges through a conductor.
Distractor 2	A material that has a high resistance.
Distractor 3	A material that resists the flow of current to generate heat.
Item 10 ID	MEF2.2.2
Question	Rubber and glass are good insulators because:
Correct Answer	Their electrons are tightly bound to their atoms.
Distractor 1	Their electrons are easily shared by adjacent atoms.

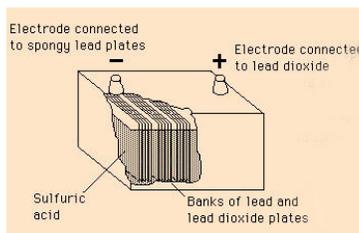
Distractor 2 They have low resistance.
Distractor 3 They provide mobility for negative charges.

Item 11 ID **MEF2.1.2**

Question Electrons are more mobile in conductors than in insulators because:
Correct Answer **Electrons are loosely bound in the atom's outermost shells.**
Distractor 1 They are the only particles that carry the elementary charge.
Distractor 2 They are more negatively charged than those in insulators.
Distractor 3 Each electron seeks to hold the excess charges given by the substance.

Item 12 ID **MEF2.4.2**

Question A common chemical battery, such as a lead-acid battery, derives its electrical energy from energy released from chemical reactions. A schematic of a battery is provided in the diagram.



Which of the following is true about the production of electricity within a lead-acid battery?

Correct Answer **The reaction of lead and lead oxide with the sulfuric acid produces a voltage stored in the battery.**

Distractor 1 The reaction of lead and lead oxide produces a current measured in Volts, which are stored in the battery.

Distractor 2 The lead electrode supplies negative ions and is the negative terminal; a current flows from one electrode to the other.

Distractor 3 The lead dioxide electrode supplies positive ions and is the positive terminal; a current flows from one electrode to the other.

Item 13 ID

MEF2.5.1

Question

This photo represents an example of a very basic electric circuit.



Correct Answer

Which of the following statements is true about this type of circuit?
This circuit makes a pathway for a current to move from high electrical potential energy to low.

Distractor 1

This circuit makes a pathway for electrons to gain electrical potential on their way their way to the positive terminal.

Distractor 2

This circuit makes a pathway for “positive electrons” to flow through the wire.

Distractor 3

This circuit enables the change of low electrical potential to high electrical potential energy to create a current.

Item 14 ID

MEF2.6.1

Question

In a simple electric circuit containing a lightbulb, a current of 1.0 amp means that:

Correct Answer

The circuit delivers one coulomb of electrons through a bulb every second.

Distractor 1

The circuit delivers 1 electron through a bulb every second.

Distractor 2

The energy the bulb delivers is not a function of the current.

Distractor 3

The energy flowing through the bulb is independent of the energy of the electrons flowing through the circuit.

Item 15 ID

MEF2.6.4

Question

The following statement describes a Watt:

Correct Answer

A Watt equals one Joule of energy expended per second.

Distractor 1

A Watt of electrical energy substantially differs from a Watt of mechanical energy.

Distractor 2

A Watt is defined as the change in voltage per unit time.

Distractor 3

The Watt described on a lightbulb is independent of the resistance of the lightbulb.

Item 16 ID MEF3.1.3

Question Electric fields vary in strength according to the inverse square law. This means that

Correct Answer **The force exerted on a charged object that is three times the distance from the center of the field is one-ninth as great as the force on a charged particle at the center.**

Distractor 1 The force exerted on a charged object that is three times the distance from the center of the field is nine times as great as the force on a charged particle at the center.

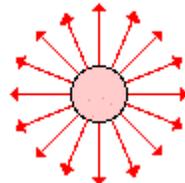
Distractor 2 The force exerted on a charged object that is three times the distance from the center of the field is three times as great as the force on a charged particle at the center.

Distractor 3 The force exerted on a charged object that is three times the distance from the center of the field is one third as great as the force on a charged particle at the center.

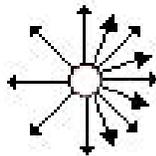
Item 17 ID MEF3.1.5

Question Choose which diagram correctly depicts the electric field of a negative charge.

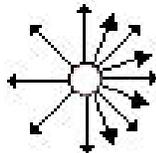
Correct Answer



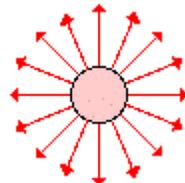
Distractor 1



Distractor 2



Distractor 3

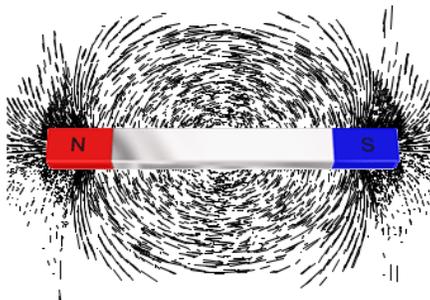


Item 18 ID

MEF3.2.3

Question

A student places a bar magnet on a smooth surface containing iron filings. The filings arrange themselves according to the diagram.



Correct Answer

The student's observation allows the following statement to be made:
Magnets are surrounded by imaginary lines of force that exert force to orient the filings along the field lines in a definite pattern.

Distractor 1

Magnets are surrounded by magnetic fields that are constant in strength but vary in direction.

Distractor 2

The greater the density of field lines, the greater the repulsion from one pole to each pole of a similar bar magnet.

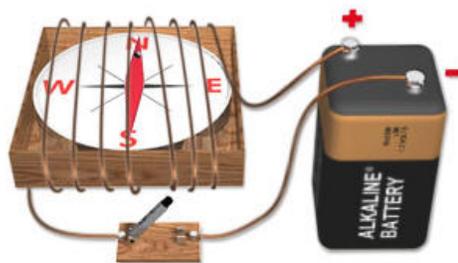
Distractor 3

The greater the density of the field lines between the poles, the greater the attraction of almost all of the metals in the Periodic Table to the magnet.

Item 19 ID

MEF3.3.3

Question



The apparatus in the diagram can show if an induced current influences the direction of a compass needle. Switching the current on

Correct Answer

Creates a magnetic field that counteracts the effect of the magnetic field of the Earth and changes the direction of the compass needle.

Distractor 1

Does not affect the alignment of the compass needle since it is affected only by the magnetic field of the Earth.

Distractor 2

Creates a magnetic field that forces the compass needle to align itself parallel to the Earth's magnetic field.

Distractor 3

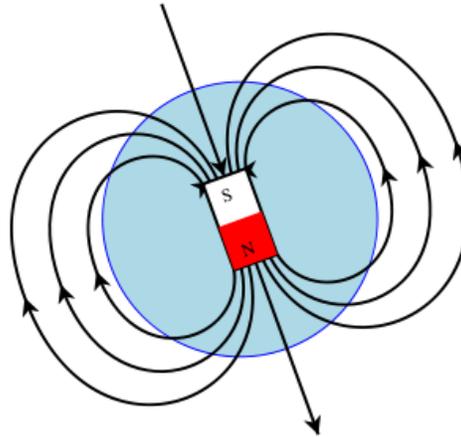
Does not create a magnetic field, only an electric field that has no influence on the magnetic field of the Earth.

Item 20 ID

MEF3.2.5

Question

The Earth's magnetic field is represented in the field line diagram.



Which of the following statements best explains the existence of the Earth's magnetic field?

Correct Answer

The Earth's magnetic field exists because currents move in the outer core producing electric currents.

Distractor 1

The Earth's magnetic field exists because lodestone and metallic minerals are found in the crust.

Distractor 2

The Earth's magnetic field exists because the Earth's core largely consists of mono-polar materials.

Distractor 3

The Earth's magnetic field exists because solar winds from the sun strip electrons off of the crust near the northern pole, making the Earth into a huge bar magnet.

Item 21 ID

MEF3.4.3

Question

In 1820, Hans Christian Oersted noted that an electric current influenced the movement of a compass needle. He noted the following:

Correct Answer

The needle of the compass tended to be at right angles to the wire carrying the current.

Distractor 1

The needle of the compass was attracted to the wire carrying the current.

Distractor 2

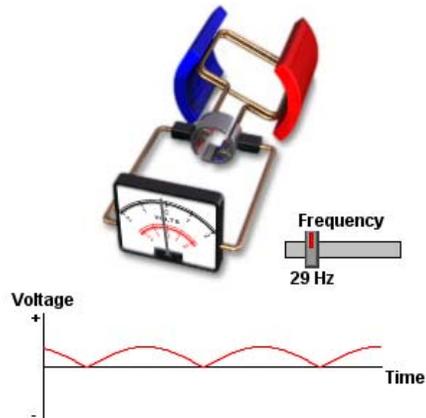
The needle of the compass was repelled by the wire carrying the current.

Distractor 3

The needle of the compass oscillated back and forth in alignment with the alternating current flowing through the wire carrying the current.

Question

In 1831, Faraday introduced the concept of an electric generator. The diagram depicts a simple electrical generator similar to the type of generator Faraday described.

**Correct Answer****Distractor 1****Distractor 2****Distractor 3**

Which of the following ideas assisted the creation of the generator?

The magnetic fields must change to induce a current in the wire.

Parallel wires carrying currents create force fields that always repel one another.

Currents flowing in the same direction create magnetic fields that always repel one another.

The attractive force that a magnet exerts on a current carrying wire is fundamental to creating an electric generator.

Appendix H:
Example Survey Invitations and Informed Consent

Invitation Example 1: Wave 1

Dear [First Name of Educator],

IF you are currently teaching in grades 3–6, you are invited to participate in a research study focused on self-directed online professional development in science education. It will only take 20 minutes of your time.

You have been selected because you have accessed one or more of NSTA’s SciPacks through the NSTA Learning Center. You completed pre- and postassessments in science content, and you passed the final assessment. For an overview of NSTA’s SciPacks visit <http://learningcenter.nsta.org/scipacks.aspx>.

Value of Your Participation

Your participation in this study would help provide valuable insight to instructional designers who create online web-based professional development. Additionally, your feedback will help inform science education administrators and leaders who are charged with the selection of effective e-PD resources on your behalf. Finally, your contribution will help inform current theories in distance education that are examining learner-content interaction strategies.

Confidentiality and Anonymity

Rest assured your participation in this study will be completely confidential and your anonymity will be protected through assigning unique codes to each participant and his or her data.

Recognition of Participation

To thank you for your participation, NSTA will provide you with a free 1-year subscription to the NSTA SciPack of your choice (\$39.99 value).

What is involved?

- Teachers in grades 3–6 that agree to participate will access a 44-question online survey via the internet.
- You will spend approximately 20 minutes completing the survey by March 15, 2010.

Next steps:

- As the primary researcher, I will be your contact if you have any questions concerning the study before agreeing to participate. You can reach me, Al Byers, at 703.312.9294 or by email: abyers@nsta.org.
- Reply to this email confirming your desire to participate, and only if you are teaching in grades 3–6.

- A follow-up email sent to those who wish to participate will include a recruitment information document with more details about the study, the survey URL, password, and your unique identifier code to ensure anonymity and confidentiality for the study.

Many thanks for those who can assist me in developing resources that will help teachers become the best they can be!

Sincerely,
Al Byers
Assistant Executive Director
e-Learning and Government Partnerships
National Science Teachers Association
abyers@nsta.org
703-312-9294

Invitation Example 2: Improvement in Style, Selectivity, Feedback and Incentives

Dear [first name of educator]

IF you are currently teaching or are preparing to teach in grades 3–6, you are invited to participate in a research study focused on self-directed online professional development in science education. **I now have 85 who have responded and only need 15 more to complete my research!**

You have been selected because you have accessed one or more of NSTA's SciPacks through the NSTA Learning Center. You completed pre- and postassessments in science content, and you passed the final assessment.

Recognition of Participation

As a thank you for your participation you will receive a free NSTA e-book of your choice from over 127 available (up to a \$37 value depending on the e-book selected), and be entered to win 1 of 15 Apple iPod Touches that will be raffled away (a \$200 value). **Given approximately 100 will be needed to complete the research; you have a 14% chance of winning an iPod Touch!**

Value of Your Participation

Your participation in this study would help provide valuable insight to instructional designers who create online web-based professional development. Additionally, your feedback will help inform science education administrators and leaders who are charged with the selection of effective e-PD resources on your behalf. Finally, your contribution will help inform current theories in distance education that are examining learner-content interaction strategies.

Complete a 25 question survey and receive a free NSTA e-Book of your choice. Over 127 e-books are available for your selection!



NSTApress®

Plus be entered to win
1 of 15 Apple iPod Touches!



Confidentiality and Anonymity

Rest assured your participation in this study will be completely confidential and your anonymity will be protected through assigning unique codes to each participant and his or her data.

What is involved?

- Teachers in grades 3–6 that agree to participate will access a 25-question online survey.
- You will spend approximately 20 minutes completing the survey.

Next steps:

- As the primary researcher, I will be your contact if you have any questions concerning the study before agreeing to participate. You can reach me, Al Byers, at 703.312.9294 or by email: abyers@nsta.org.
- Reply to this email confirming your desire to participate, and only if you are teaching in grades 3–6.
- A follow-up email sent to those who wish to participate will include a recruitment information document with more details about the study, the survey URL, password, and your unique identifier code to ensure anonymity and confidentiality for the study.

Many thanks for those who can assist me in developing resources that will help teachers become the best they can be!

Al Byers

Assistant Executive Director
e-Learning and Government Partnerships
National Science Teachers Association
1840 Wilson Blvd., Arlington, VA 22201-3000
Web: <http://www.nsta.org>
PH: 703-312-9294

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subjects

Examining Learner-Content Interaction Importance and Efficacy in Online, Self-Directed Electronic Professional Development in Science for Elementary Educators in Grades Three – Six

Investigator(s)

Dr. John Burton

Mr. Albert Byers

I. Purpose of this Research/Project

Given the lack of improvement on student achievement in science education at both national and international levels over the last several decades, the research community is interested in exploring how to increase teacher impact through enhanced online professional development. Many elementary educators may benefit from improved science content knowledge given they have little exposure in this area during their preservice education. Given the challenge and expense of providing this support at a level scalable and sustainable on a national level, this study seeks to understand what types of online professional development interaction strategies provide the greatest satisfaction and learning for teachers in grades 3–6 when looking at teachers' age, years teaching experience, and preferences for learning.

An online survey will be administered to teachers who volunteer to participate. Educators from a pool over over 850 teachers who have already completed both a pre- and postassessment and passed a final assessment at the conclusion of a self-paced web module from the National Science Teachers Association (NSTA) called "SciPacks" will determine who is eligible to complete the online survey.

The survey will capture data on the following:

- Teacher demographic data (age, years teaching experience, subjects taught, etc.)
- Teachers' preferences for different types of online content interaction
- An individual's preferred learning style

The different types of learning interaction content strategies that will be examined are:

- Online Simulations
- Interactive Reference (text, images, animations, and check-your-thinking questions)
- Personal Feedback (embedded and end-of-topic multiple-choice quiz questions)
- Hands-On Learning Opportunities (embedded tangible activities to facilitate learning)
- Pedagogical Implications (grade-level specific instructional strategies for teaching)

II. Procedures

The research procedure will be very simple. Teachers who meet the parameters for the study (described below) will be invited to complete a single online survey. The survey contains

approximately 44 questions and will capture teachers' age, years teaching experience, grade level(s) taught, and teaching licensure, as well as a series of questions to gauge their preferences for different online content interaction types. It will take 20 minutes to complete.

The following parameters will determine which teachers are eligible to complete the online survey:

- Currently teaching science in grades 3–6
- Completed the pre- and postassessment for a particular NSTA science content web module (SciPack)
- Completed and passed the final assessment for the same web module (SciPack)

Access to the survey will be sent via email during the Spring–Summer 2010 timeframe with a 2-week window for completion once received.

Al Byers, primary researcher for this project, under the advisement of Dr. John Burton at Virginia Tech, will analyze the survey data as well as the pre- and postassessment and final assessment data associated with the web module(s) the teacher completed online that made them eligible for participation in this study. Confidentiality of all data will be protected as described in the section below.

III. Risks

There are no anticipated risks for teachers participating in this study other than any discomfort that may result from the hour one spends completing the online surveys. In this regard, teachers should take precautions in making sure they maintain proper posture when using input devices such as a mouse and keyboard, and distance from the computer screen to avoid any unnecessary eye strain. They should take a break between completing the first and second survey to alleviate any potential discomfort to eyes or posture.

IV. Benefits

Findings from this research will inform and benefit instructional designers and curriculum developers who create online professional development as to which interactive content strategies may be most engaging for adult learners and which strategies may maximize learning given various demographic data and adult learning preferences. Additionally, this research will inform education administrators who are charged to make financial and programmatic decisions regarding the suite of professional development opportunities available for teachers within their schools, districts, and states. Finally, data from this research support a major thrust of current research in online professional development and will inform an emerging theory concerning the degree and nature of online content interaction for adult learners. **The researchers will post a URL that shares a summary of the research results via email when the dissertation is completed by August-September 2010.**

V. Extent of Anonymity and Confidentiality

Educators agreeing to participate will be anonymous. A method of assigning a separate code to each name that is kept separate from the original data will allow the research and analysis to occur while protecting the names and data of each individual. **Participants in this study are**

assured the utmost confidentiality in all data that is collected. The data will reside on no more than two computers for capture and analysis. After the survey is complete the data will be deleted and will not be hosted on any internal or external network or internet server. **At no time will the researchers release any individual identifying data (e.g., scores, geographic location, etc.) from the study to anyone other than individuals working on the project without your written consent.** It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

Teachers participating in the study will receive an electronic promotional code at the conclusion of the survey (and/or via email if they fail to complete the survey) that will allow them to add one web-based NSTA Press e-Book of their choosing to their personal library at the National Science Teachers Association e-PD portal: The NSTA Learning Center (<http://learningcenter.nsta.org>). The retail value for purchasing this e-book may be up to \$37 in value and there are currently 127 e-books from which to choose. Additionally, all will be entered to win 1 of 15 Apple iPod Touches via a raffle.

VII. Freedom to Withdraw

Subjects are free to withdraw from a study at any time. Subjects are free to not answer any questions or respond to experimental situations that they choose with no penalty. Those that only partially complete the study's requirements will still be offered a promotional code to access one NSTA e-Book for free as well as be entered to win 1 of 15 iPod Touches.

VIII. Subject's Responsibilities

Teachers who volunteer for the study will have the following responsibilities:

- Agree to allow access to their pre- and postassessment web module data and the final assessment data at the conclusion of each web module they have completed (SciPack).
- Complete one online survey (44 questions) that has teachers rank their preferences for different types of learning engagements and preferences for learning.

IX. Subject's Permission

When agreeing to participate in this study by responding to the email invitation, teachers will be providing their voluntary consent in lieu of a formal written signature and stating that they have had all their questions answered.

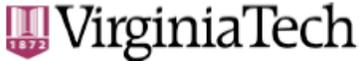
Chair, Virginia Tech Institutional Review
Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060

Should you have any pertinent questions about this research or its conduct, and research subjects' rights, or whom to contact in the event of a research-related injury to the subject, they may contact:

Investigator: Albert Byers
Telephone: 703-312-9294
e-mail: abyers@vt.edu

Faculty Advisor: Dr. John Burton
Telephone: 540-231-5587
e-mail: jburton@vt.edu

Appendix I:
Virginia Tech IRB Approval



Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
www.irb.vt.edu
FWA00000572 (expires 6/13/2011)
IRB # is IRB00000667

DATE: January 26, 2010

MEMORANDUM

TO: John K. Burton
Albert Byers

FROM: David M. Moore 

Approval date: 1/26/2010
Continuing Review Due Date: 1/11/2011
Expiration Date: 1/25/2011

SUBJECT: **IRB Expedited Approval:** "Examining Learning-Content Interaction Importance and Efficacy in Online, On-Demand Electronic Professional Development in Science for Elementary Educators in Grades 3-6", IRB # 10-018

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective January 26, 2010.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtain re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

Important:

If you are conducting **federally funded non-exempt research**, please send the applicable OSP/grant proposal to the IRB office, once available. OSP funds may not be released until the IRB has compared and found consistent the proposal and related IRB application.

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An equal opportunity, affirmative action institution

Appendix J:
Learner Preferences for Different Content-Interaction Strategies

This appendix presents the raw data across 85 participants from grades three – six that rated their preferences for the following different types of learner-content interaction strategies: (a) hands-on activities, (b) simulations, (c) personal feedback, (d) interactive reference, and (e) pedagogical implications. Four subject’s responses were removed as they did not complete the other components for the study (i.e., pre- and postassessment and passed the final assessment for their respective web modules.). A description of each of these interaction strategies with an example may be found in [Appendix C](#). A frequency distribution table across the five questions asked is followed by a figure showing the spread of the preferences across each question.

Hands-On Activities

Table 1: Aggregate Learner Survey Preferences for Hands-On Learning Content Interaction

I think this content type (hands-on)								
Answer Options	7. Strongly Agree	6	5	4	3	2	1. Strongly Disagree	Rating Average
is engaging to me.	44	34	12	10	2	3	1	5.90
facilitates my learning science content.	46	38	10	6	3	2	1	6.02
helps my retention of the science content over time.	46	32	15	7	2	3	1	5.94
facilitates teaching the science content to my students.	56	27	13	5	2	2	1	6.13
I would like to see more of this content type.	39	39	15	7	2	2	2	5.87

I think this content type (hands-on)

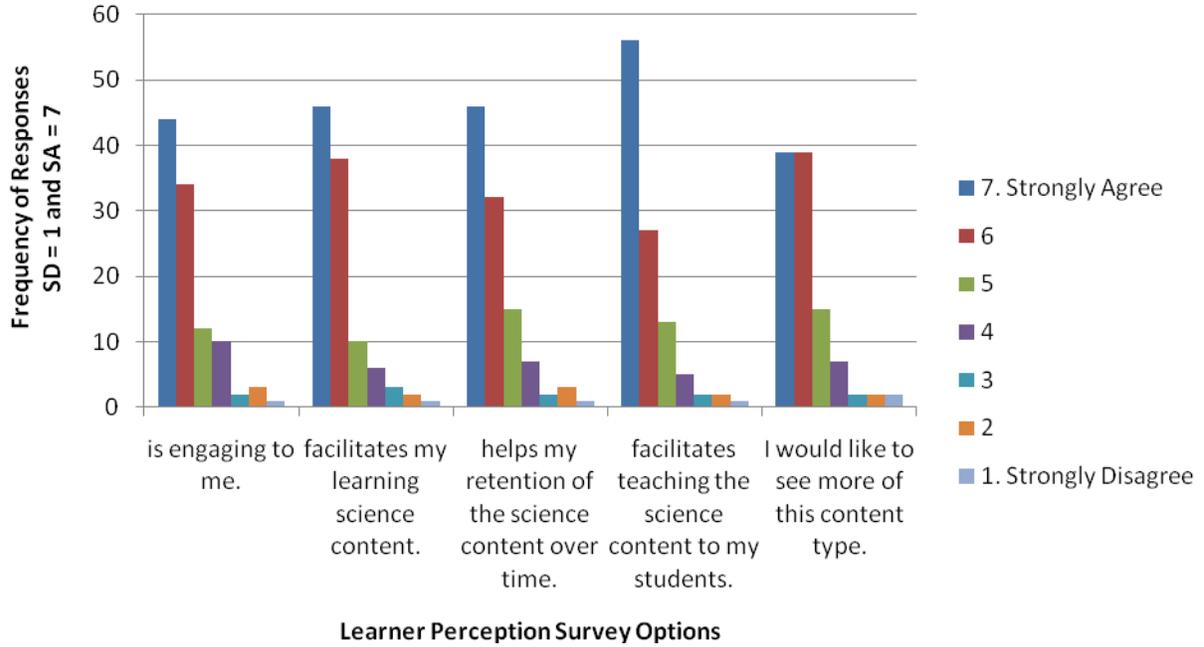


Figure 1. Aggregated learning survey responses for hands-on activities.

Simulation

Table 2: Aggregate Learner Survey Preferences for Simulation Content Interaction

I think this content type (simulations)								
Answer Options	7. Strongly Agree	6	5	4	3	2	1. Strongly Disagree	Rating Average
is engaging to me.	45	37	16	6	1	1	0	6.09
facilitates my learning science content.	54	28	19	4	1	0	0	6.23
helps my retention of the science content over time.	41	32	18	13	0	2	0	5.90
facilitates teaching the science content to my students.	38	32	22	9	3	1	1	5.81
I would like to see more of this content type.	38	37	17	9	2	3	0	5.86

I think this content type (simulation)

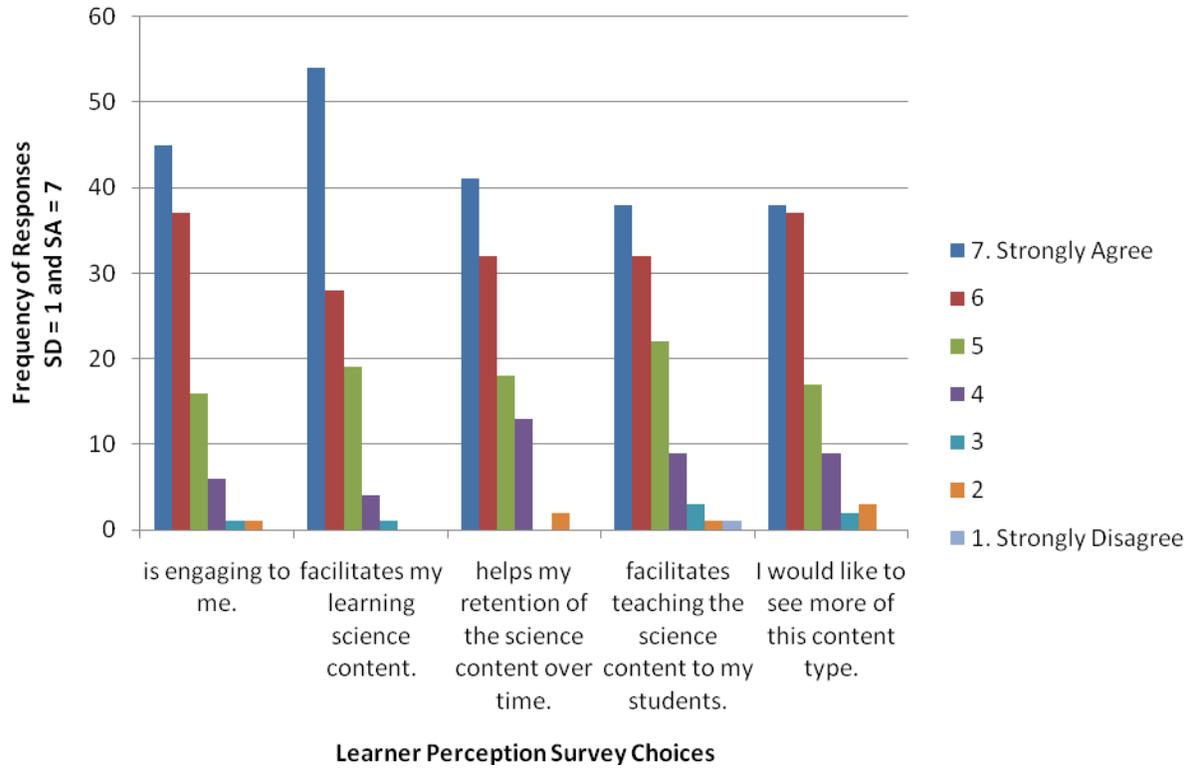


Figure 2. Aggregated learning survey responses for simulations.

Personal Feedback

Table 3: Aggregate Learner Survey Preferences for Personal Feedback Content Interaction

I think this content type (personal feedback)								
Answer Options	7. Strongly Agree	6	5	4	3	2	1. Strongly Disagree	Rating Average
is engaging to me.	32	27	32	10	3	1	1	5.64
facilitates my learning science content.	41	37	17	9	0	1	1	5.97
helps my retention of the science content over time.	38	31	22	9	3	2	1	5.77
facilitates teaching the science content to my students.	28	36	22	12	5	2	1	5.57
I would like to see more of this content type.	34	32	24	8	4	3	1	5.67

I think this content type (personal feedback)

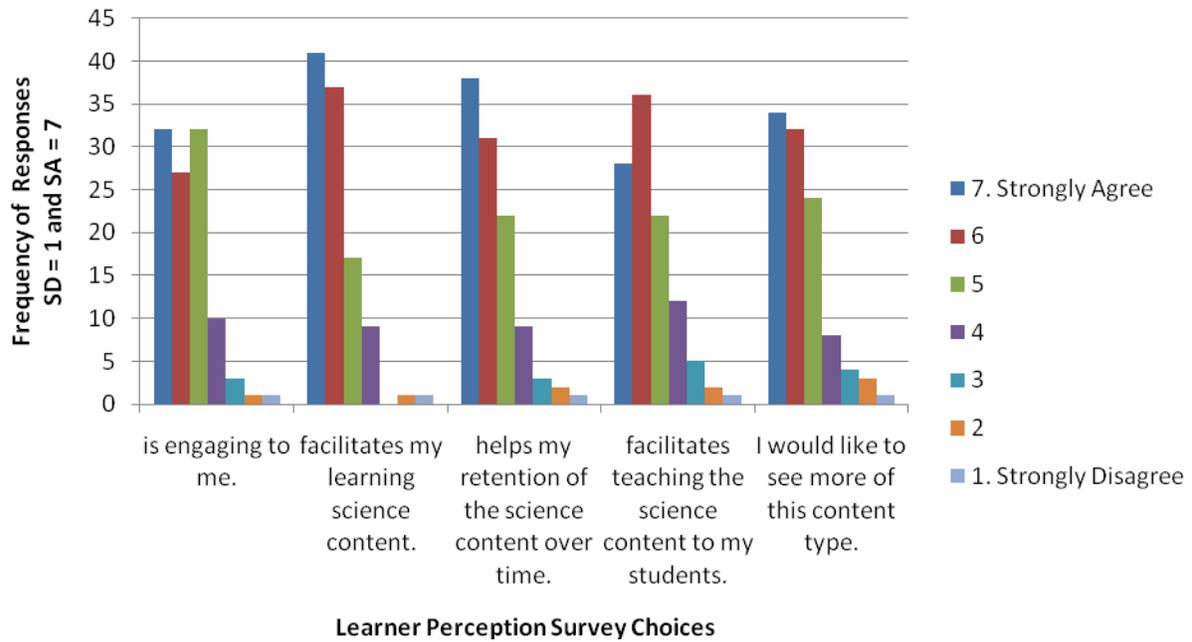


Figure 3. Aggregated learning survey responses for personal feedback.

Interactive Reference

Table 4: Aggregate Learner Survey Preferences for Interactive Reference Content Interaction

I think this content type (interactive reference)								
Answer Options	7. Strongly Agree	6	5	4	3	2	1. Strongly Disagree	Rating Average
is engaging to me.	39	41	15	5	3	2	0	5.97
facilitates my learning science content.	43	42	12	4	3	1	0	6.10
helps my retention of the science content over time.	33	41	21	5	3	2	0	5.86
facilitates teaching the science content to my students.	42	31	21	6	2	2	1	5.90
I would like to see more of this content type.	37	36	18	7	4	3	0	5.82

I think this content type (interactive reference)

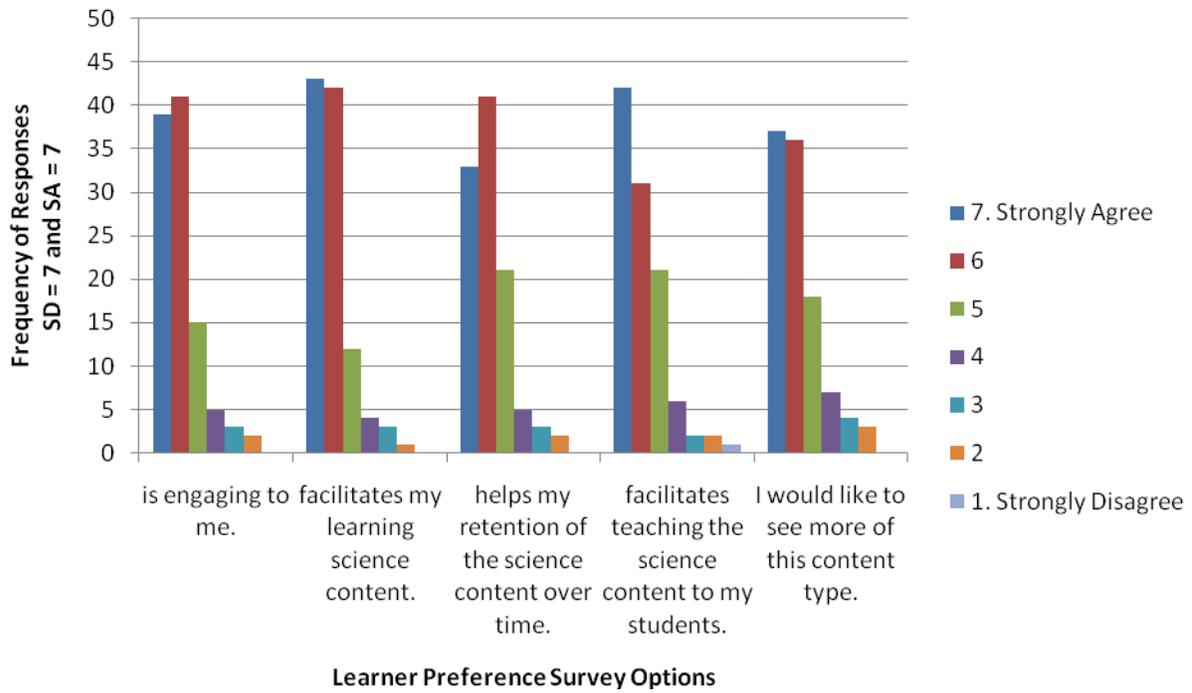


Figure 4. Aggregated learning survey responses for interactive reference.

Pedagogical Implications

Table 5: Aggregate Learner Survey Preferences for Pedagogical Implications Content Interaction

I think this content type (pedagogical implications)								
Answer Options	7. Strongly Agree	6	5	4	3	2	1. Strongly Disagree	Rating Average
is engaging to me.	14	20	24	19	15	7	7	4.53
facilitates my learning science content.	13	27	19	21	14	7	5	4.65
helps my retention of the science content over time.	9	19	25	24	14	8	7	4.37
facilitates teaching the science content to my students.	27	17	25	20	9	6	2	5.07
I would like to see more of this content type.	16	15	26	19	13	11	6	4.48

I think this content type (Pedagogical Implications)

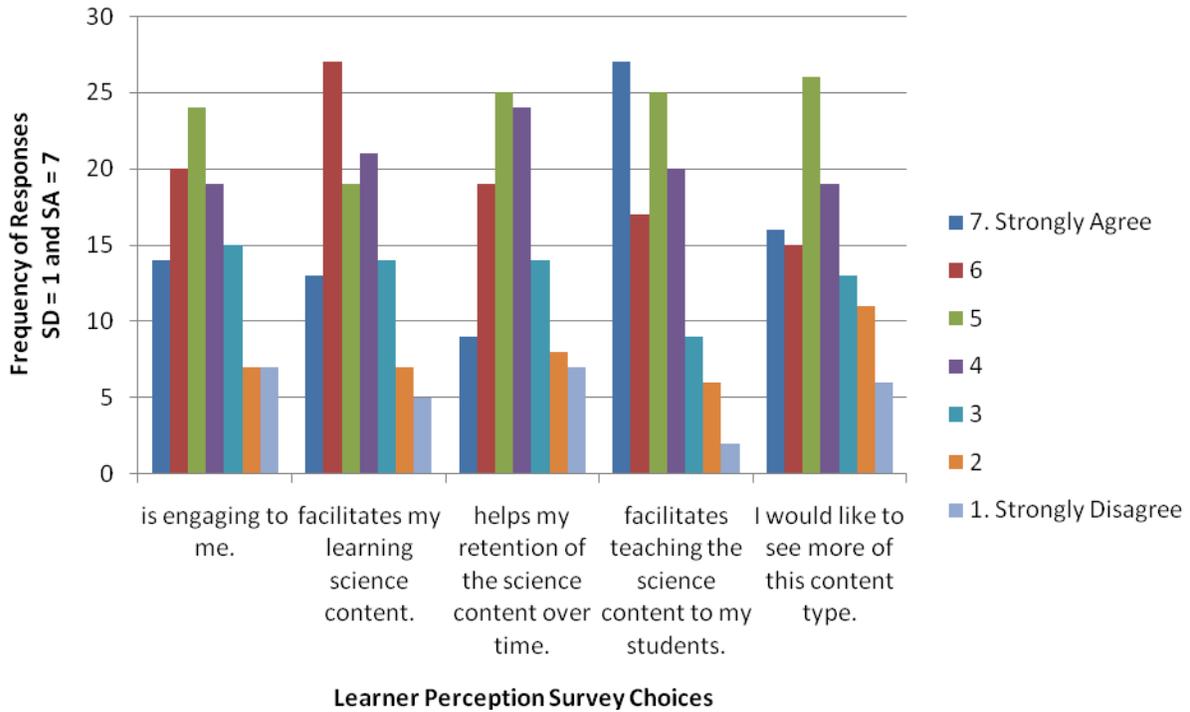


Figure 5. Aggregated learning survey responses for pedagogical implications.

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