Question 1: What is the current status of online teacher professional development? What trends exist in the area of OPD for teachers of science, particularly at the upper-elementary level? Finally. What research has been conducted with regard to OPD for teachers? Please describe general themes as well as relevant findings, particularly related to science education. How might research in this area inform the development of future OPD for science teachers?

This response will explicate a brief review of the latest research on the components of teacher professional development (TPD) in general as related to the landscape in science education and that of elementary teachers of science, and then expand the discussion concerning online teacher professional development (oTPD), focusing on the upper elementary level research as available. General trends in TPD and oTPD will be reviewed, as well as a research synopsis of current themes in oTPD, concluding with implications for future research. A foray into the research on e-learning and its potential in areas such as learning objects will illuminate an area ripe for science education to address the issues of scale and sustainability in online professional development. Before jumping into the various derivatives of oTPD, a definition for teacher professional development and the extent literature in support of the recent findings regarding high quality professional development in general should precede and seek to inform its online counterpart.

What is Professional Development?

Depending on ones' perspective as to the purpose of professional development (PD), answers may vary from a narrow view of release time 3-4 days a year to complete required hours for recertification to one of a systemic nature that views professional development as part of an on-going, intentional, iterative process of teacher improvement over an entire professional career, instantiated as part of the culture of learning within a school with the goal of improving teacher learning and ultimately student learning (Elmore, 2004; Guskey, 2000; Hewson, 2007; Loucks-Horsley, 1999). The issue is complicated given a variety of offerings both online and face-to-face, but for the purposes of this review, by focusing on the primary agent of change for professional development, the teacher, a concise definition from Feiman-Nemser (2001) may suffice:

> On the one hand, [professional development] refers to the actual learning opportunities which teachers engage in—their time and place, content and pedagogy, sponsorship and purpose. Professional development also refers to the learning that may occur when teachers participate in those activities. From this perspective, professional development means transformations in teachers' knowledge, understandings, skills, and commitments, in what they know and what they are able to do in their individual practice as well as in their shared responsibilities (Feiman-Nemser, 2001, p. 1038).

Online professional development really has the same purpose as stated above, with the primary difference being these experiences as mediated electronically online, thus affording a shifting of time, place, and space in which the learning occurs between other learners and instructors, with the addition of rich and varied media to support learning (Dede, 2006b; Hiltz & Goldman, 2005; Rice, Hiltz, & Spencer, 2005; Vrasidas & Glass, 2004). An initial broad stroke review of the literature will sketch the PD landscape from a general perspective and then use a finer brush to color in the details regarding online professional development in particular, citing studies illustrative of current trends and research in elementary science education.

Professional Development and Elementary Education: The Current Landscape

From a common sense and broad point of view, few would question the importance of the teacher in the process of educating our students, and a large body of empirical research supports these findings (Monk, 1994; National Commission on Teaching and America's Future, 1996; Whitehouse, Breit, McCloskey, Ketelhut, & Dede, 2006). While there is much debate regarding how best to prepare and certify prospective teachers entering the profession (Abell Foundation, 2001; Darling-Hammond, Barnett, & Thoreson, 2001; Darling-Hammond & Chung, 2002; Wilson, Floden, & Ferrini-Mundy, 2002), few argue about the important transformational knowledge, skills, abilities, beliefs, and professional development support teachers need both upon entering the classroom and throughout their professional careers (Darling-Hammond, 2006; Little, 1993; National Commission on Teaching and America's Future, 1996; Shulman, 1986, 1987; Sykes, 1996). National education reform efforts and legislation also 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, & Institute of Medicine of the National Academies, 2007; National Staff Development Council, 2008; No Child Left Behind Act ", 2001; Sherwood & Hanson, 2008). A convergence between three major education initiatives places the current focus on teachers and in turn, their professional development: (a) national standards reform efforts calling for improved science content knowledge and ways to teach it, (b) requisite achievement levels for every child in the United States with teacher and school accountability measuring the same, and (c) an awareness of our national and international standing in education as compared with other developed nations (Hewson, 2007). Please see the response to the question concerning the differences between pedagogy and pedagogical content knowledge for a review of reform efforts and a sample of the United State’s national and international rankings in science education.

Earlier large scale teacher professional development attempts invested substantially in multi-year, multimillion dollar efforts, funding thousands of professional development projects, reaching hundreds of thousands of teachers (Elmore, 2004; Sherwood & Hanson, 2008), only to find a large number of elementary teachers still lacking a deep understanding of content knowledge and pedagogical content knowledge in science, and an ability to design and deliver conceptually-rich lessons in the way espoused by the national reform standards (American Association for the Advancement of Science, 1993; Banilower, Heck, & Weiss, 2007; Council of Chief State School Officers, 2008; Garet, Porter, Desimone, Birman, & Yoon, 2001; Horizons Research, 2006; National Research Council, 1996; The Council of Chief State School Officers, 2007). Research is beginning to mount behind an emerging consensus of what constitutes high quality professional development (Elmore, 2004; Feiman-Nemser, 2001; Hawley & Valli, 1999; Loucks-Horsley, 1999; National Staff Development Council, 2008), and its link to student achievement, which in part may comprise: (a) a focus on deep conceptual understanding of content knowledge linked closely with its respective pedagogical implications on how to teach it, (b) knowledge of how students learn based upon and building from their prior knowledge and experiences, (c), a coherent suite of longer duration opportunities closely coordinated with school teams, tied to curriculum and informed by student learning (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000; Garet, et al., 2001; Hawley & Valli, 1999; Kennedy, 1998; National Staff Development Council, 2008; Supovitz & Turner, 2000; Wilson & Berne, 1999). Research supports professional development that is of longer duration and higher contact hours

(50-80 plus hours per year) as necessary to support teacher growth and classroom transfer (Banilower, et al., 2007; Garet, et al., 2001; Supovitz & Turner, 2000; US Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, & Regional Educational Laboratory Southwest, 2007; Yoon, Duncan, Lee, & Shapley, 2008), but current data reflect elementary teachers on average receiving less then 16 hours per year, which may be insufficient to effect positive change in their practice or student learning (Horizons Research, 2002; National Staff Development Council, 2008; US Department of Education, et al., 2007).

While opinion on these and other features of “effective” professional development congeal, the research supporting this consensus is not yet definitive (Banilower, et al., 2007; Guskey, 2003; Wayne, Yoon, Zhu, Cronen, & Garet, 2008). As some aptly convey, the sociocultural context of schools is extremely diverse, complex, and interconnected in a number of ways, thus making causal relationships between the effects of professional development on student achievement an arduous task not for the faint of heart (Clarke & Hollingsworth, 2002; Guskey, 2003; Hewson, 2007). Be that as it may, the need for high quality professional development is great, as there are approximately 1.7 million elementary teachers of science in the United States who, as demonstrated below, need support in their science knowledge and skills (U.S. Department of Education & National Center for Education Statistics, 2009). 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 field to gain insight into teachers' understandings in science and found that approximately 80% of 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 then science or science education (e.g., general education) (Horizons Research, 2001), thus revealing a potential need for science content and pedagogical content knowledge at the elementary and middle school levels. Finally, regarding teacher self-confidence in how well they 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, environmental science and biology, but lower confidence in physical science and chemistry (Horizons Research, 2001). See prelim question three regarding pedagogical content knowledge for a more thorough discussion on the impact of teacher knowledge and its relationship and impact on student learning.

Couple these data with the fact that gross expenditures on professional development were approximately $1.5 billion dollars for the 2004-2005 school calendar year (American Institutes for Research & RAND Corporation, 2007), with the numerous PD offerings now appearing online, and the imperative to research the effectiveness and efficiency of current and future professional development models is axiomatic (Dede, 2006a; Dede, Ketelhut, Whitehouse, Briet, & McCloskey, 2009). As Dede (2006a) states in his review concerning the importance for research in online professional development:

> Currently many initiatives in online teacher professional 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 then later when a better sense of long-range impact is attainable. (2006a, p. 2).

With the broad brush strokes now applied to illustrate the need for elementary teacher professional development, and a vantage point created within our landscape to focus our view towards online PD, let's begin to add more detail to our canvas by coloring in a few of the current trends and future directions in online professional development.

Current Trends in Online Professional Development

Trends, especially those involving disruptive technologies, such as e-learning, are extremely difficult to predict given unforeseen technical constraints and market instabilities, which often more portend premonitions for the future, rather then the needs of the present (Boon, Rusman, Van der Klink, & Tattersall, 2005). That said there are established practices such as: (a) monitoring, (b) opinion of experts, (c) trend analysis, (d) modeling, and (e) scenario construction, as well as analytical protocols that enhance clairvoyance, permitting one to make educated guesses about future trends (Boon, et al., 2005). For the purposes herein, a "rear view mirror" monitoring perspective will be applied to foreshadow what lies up the road ahead. Data presented is based on survey trend data, as well as monitoring and expert opinion by reputable prognostications and analysts who focus on technology (Pew Internet & American Life Project, 2009; The New Media Consortium & EDUCAUSE Learning Initiative, 2009; The Sloan Consortium, 2008).

The Biggest Trend and Overarching Theme: Learner Control and Community

Several recent discussions in online professional development cite advantages that mirror those that have been espoused in the field of distance education (DE) for some time (Dede, et al., 2009; National Research Council, 2007). Online learning, whether labeled distanced education, online professional development, e-learning, or web-based asynchronous or synchronous learning, at its essence permits learners to actively engage with other learners and the instructor in reflective discourse as they consume rich and varied media, and to a large degree regulate the time, place, and pace of their learning (Dede, 2006b; Hiltz & Goldman, 2005; Rice, et al., 2005; Vrasidas & Glass, 2004). The biggest single trend throughout the history of distance education, which started from the early mail correspondence courses, and progressively migrated through various technologies, such as radio, TV, teleconferencing, satellite-based videoconferencing, and now, computer mediated web-based learning is the expansion and degree of social interaction permitted between fellow learners and the instructor (Bernard, et al., 2004; National Research Council, 2007; Vrasidas & Glass, 2004). Drawing on the situated learning literature (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), social constructivist learning theories of Vygotsky (1978), and supporting what we know about the building of knowledge through discourse (Bransford, et al., 2000), probably the single most prevalent theme in online professional development for teachers today is that of building a community of professionals, who are no longer isolated within the walls of their classroom, but able to engage in a communal discourse with colleagues, experts, instructors, coaches, and mentors, who would not be available otherwise (Dede, 2006a; Henderson, 2007; McInnerney & Roberts, 2004; National Research Council, 2007; Oliver, Herrington, Herrington, & Reeves, 2007; Schlager & Fusco, 2003; Vrasidas & Glass, 2004). While few would disagree with this proposition, the meteoric rise in social networking coupled with the increasing learner demand to control the flexibility of his or her learning from both a media, social, and pacing perspective, is inspiring researchers to explore online learning environments that provide on-demand “just-in-time” access that is delivered beyond the “walls” of the virtual online course, where currently, the primary foci of learning is instructor moderated discourse within fixed stop-and-start timeframes (Asbell-Clarke & Rowe, 2007; del Valle & Duffy, 2009; Dickey, 2006; Gibbs & Gosper, 2006; McLoughlin & Lee, 2008a, 2008b; Nesbit & Winne, 2003; Rhode, 2009; Tu, 2005; Turker, Gorgun, & Conlan, 2006; Walker, Downey, & Sorensen, 2008). A recent report by the Pew Internet & American Life Project (2009) reported that participation in social networking, while currently savored for personal predilections, has quadrupled over the past four years, with 75% of adults between the ages of 18 and 24 in the United States having a profile on a social networking site. “The Personal Web,” was coined to denote another emerging trend that predicts within two to three years everyone will have their own unique online space utilizing a suite of free and easily accessible tools to facilitate personal and professional collaboration, reflection and learning (The New Media Consortium & EDUCAUSE Learning Initiative, 2009). Seeing the impending tide, a few researchers are beginning to advocate design principles, tool enhancements, and pedagogies to navigate these waters (Dron, 2007; Gibbs & Gosper, 2006; McLoughlin & Lee, 2008b; Nesbit & Winne, 2003; Tu, 2005). Others, who perceive this rise with a less then optimistic perspective, stack sandbags to stem the flow, possibly with just concern (Sawchuk, 2009). It would seem that the current course delivery systems such as Blackboard, have capabilities that are too narrow from current learning theory perspectives, and do not easily facilitate multi-user group work that incorporates problem-based, authentic, or project-based collaborative learning that integrates Internet and portal-based resources or collaborative knowledge construction tools such as: (a) wikis and blogs; (b) wide scale sharing of files and URLs; (c) intelligent learning agents; (d) online multi-user immersive game environments, and (e) varied media, such as learning objects, as part of the online experience (Asbell-Clarke & Rowe, 2007; Dickey, 2006; Gibbs & Gosper, 2006; Jiang, Parent, & Easmond, 2006; Kim, Bonk, & Oh, 2008; McLoughlin & Lee, 2008a; Moller, Foshay, & Huett, 2008; Tu, 2005). Combined with this critique of existing course delivery platforms is the discussion regarding the importance of the online instructor, instructional design strategies (e.g., ill-structured problems, case studies, role playing, simulations, or self-directed, self-regulated learning), and the challenges of supporting effective problem-based and project-based online learning experiences (Cameron, Morgan, Williams, & Kostelecky, 2009; Dennen, Darabi, & Smith, 2007; Gibbs & Gosper, 2006; Jiang, et al., 2006; Kupczynski, Brown, & Davis, 2008; Mentis, 2008; Scripture, 2008; Tu, 2005). From a different perspective altogether, others recognize the need for differentiated professional development in support of teachers' unique needs and career status (Feiman-Nemser, 2001), and some advocate for large electronic PD portals where teachers may plan and select from a list of peer-vetted and varied delivery offerings (L. Anderson & Olsen, 2006).

Hyperbole Learning or Hyper-speed Learning: Mobile Smart Phones and PDAs

There appears to be a predicted and real trend in the research concerning mobile smart phones and PDA's for learning, given their affordability, portability, immediacy of voice and text interaction, and the interactivity of overlapping integrated technologies which in part include: (a) uploading and downloading of geo-tagged digital video and images, (b) always on Internet access for real-time text and audio communication, (c) probe-sensing technology for real time data analysis, (d) immediate access to online libraries for diagnostic and telemedicine efforts, (e) time-shifting content consumption, and (f) even yet to be developed applications that are immediately downloadable for free or for a small fee (Caudill, 2007; Ducut & Fontelo, 2009; Peters, 2007; Rekkedal & Dye, 2007; The New Media Consortium & EDUCAUSE Learning Initiative, 2009). While recent research reveals challenges porting certain content to mobile phones for learning given issues with screen size, text input, processing power, and battery life (Caudill, 2007; Rekkedal & Dye, 2007), given over 1.2 billion mobile phones are poured into the marketplace each year (The New Media Consortium & EDUCAUSE Learning Initiative, 2009), efforts are expanding to explore their potential from the perspective of just-in-time situated learning, electronic performance support, formative diagnostic feedback, and as an extension to existing online course delivery mechanisms (Ducut & Fontelo, 2009; Peters, 2007; Rekkedal & Dye, 2007). From the vantage point of the younger learners, who are digital natives using this technology transparently and fluently within their daily lives, providing exposure and utilization of these “smart” devices within the context of larger professional development experiences for teachers seems worthwhile to help overcome the generational digital divide (McLoughlin & Lee, 2008b; Peters, 2007; Sujo de Montes, 2009; Wiske, 2006). Care should be taken to explore the appropriate and effective affordances the platform provides, attempting to avoid the hyperbole often associated with all new technologies (Amiel & Reeves, 2008; Mentis, 2008). Explication of the research regarding mobile access for online PD occurs in greater detail in prelim question two. Suffice it to say, current lines of research in mobile technologies are a welcome departure from the earlier lines of media comparison studies.

Some Trends Never Die: Online and Face-to-Face Comparison Studies

Literature across disciplines and within the field of distance education include decades of studies regarding different forms of media comparisons and of late, comparing distance education course effectiveness with face-to-face counterparts on dependent measures of student achievement, which in an overwhelming majority of cases, find either no significant difference (NSD) between the two (Russell, 1983), or wide variations either for or against its “equivalent” (Bernard, et al., 2004). There are a few exceptions. In the recent study by Harlen and Doubler (2004), they compared an online cohort of elementary and middle level science teachers with an on-campus equivalent as both completed a 13-week course designed to increase science content knowledge and inquiry-based learning. They concluded the online group showed significant improvement in content knowledge and self-confidence compared to the on-campus teachers. A further review of these findings will ensue within the review of literature for this theme.

Different explanations and conclusions are purported for the large majority of NSD findings, such as errors in methodology and design (The Institute for Higher Education Policy, 1999), or equality in learning outcomes between online and its face-to-face counterpart (Russell, 1999). Reasons for the comparisons vary, but typically include a need to determine the success of the online course (Lockee, Moore, & Burton, 2001), or the necessity to make sound investment decisions based on the effectiveness of the technology (Bernard, et al., 2004). Scholars knowledgeable in educational technology and communications are informing the broader community of Clark’s (1983, 1994) argument that comparisons between delivery media should not be the primary foci of study, but instead researchers should examine the appropriate mix of media, delivery modes, and instructional methods with the aim to enhance the degree of user engagement and learning (T. Anderson, 2003; Head, Lockee, & Oliver, 2002; Lockee, Moore, & Burton, 2002; Mentis, 2008). See Figure 1 in prelim exam question two for a review of Anderson’s (2003) model that presents a concise view of various affordances permitted for online learning. Researchers say comparisons between online and onsite courses are both erroneous in comparison, ill-formed for research analysis, and most likely will not contribute to the body of knowledge in the field (Bernard, et al., 2004; Lockee, Burton, & Cross, 1999; Lockee, et al., 2001; Welsh, Wanberg, Brown, & Simmering, 2003).

Existing and Emerging Trends: Online Courses and Online Professional Development

Current trends in online learning continue to expand in both the number of offerings available and in the number enrollees participating in them, with a large majority taking the form of formal moderated online courses offered through universities either as part of a degree, or a certification program (The Sloan Consortium, 2008). From a national survey of over 2,500 universities and colleges in 2007 it was found that over 3.9 million students took at least one online course that fall, reflecting a jump of 12 % from the prior year and a 12.9 % increase in overall online enrollments, which now have more then doubled since (The Sloan Consortium, 2008). Key features and components of these largely asynchronous learning opportunities include a suite tools that facilitate sharing files, student profiles, and discussions as cohorts works through weekly course syllabi over the period over 6 to 14 weeks (Asbell-Clarke & Rowe, 2007; Downing & Holtz, 2008; Hiltz & Goldman, 2005).

With respect to professional development, the offerings are plentiful and from a wide variety of providers, such as universities, informal museums, regional systemic agencies, third-party for profit businesses, and non-profit institutions (Dede, 2006a; National Staff Development Council, 2008). In 2005, the National Science Foundation sponsored a conference and review of online professional development literature that ultimately identified 10 exemplary professional development models for cross-case analysis, as well as a selection of 40 empirical peer-reviewed research studies of professional development from over 400 sampled from the literature (not all being online) (Dede, 2006b). In building upon this work, a brief review and update of selected cases will be discussed; identifying the salient contextual differences that run across the oTPD landscape. After reporting on this cross-case analysis, a review of recently selected studies in online professional development in elementary science education will follow. In selecting the online program cases for examination and discussion, Dede's (2006a) team used a number of factors to filter the final selection: (a) program quality and maturity; (b) relevance to mathematics, science, engineering and technology education; and (c) inclusion of a cross-section of models representing diverse content, pedagogical approaches, and audiences. In aggregate Dede (2006a) states "these cases present a valuable diagnostic picture about the current state of high-end online teacher professional development" (p. 5).

The case studies that include those within the K-8 science education grade levels will be illustrated in this landscape, with several peer-reviewed studies stylized in more detail in the section that follows the case reviews. All of the case studies and peer reviewed research studies that are discussed in this question may be reviewed in Table 1 located before the reference section. This location will also pertain to the remaining questions that reference figures or tables. The cases selected below succinctly present a varied range of delivery models and purposes of online PD in science education:

1. EdTech Leaders Online (ETLO) is a program that seeks to train states and district personnel in creating their own online short course content, as well as providing training in course delivery (Dede, 2006b). They also offer a suite of over 60 completed online courses which may be licensed for use at any time, with four courses for elementary science teachers in the areas of: (a) electricity and circuits; (b) Earth, sun and moon, (c) literacy and the life sciences; and (d) how to use web tools to promote inquiry-based learning (Education Development Center, 2009).

2. PBS TeacherLine and WGBH Teachers' Domain have partnered since this original case review, but succinctly stated, both offer repositories of online learning resources from their rich archive of science video and digital imagery for teachers, and have developed a suite of online courses in science education that are licensed to states and districts. Courses focus on science content and pedagogy with the aim of increasing student achievement. Currently over 41 courses are available, many at the elementary level with titles focused on areas such as inquiry, teaching reading and writing in the content area of science, plants, heredity, ecosystems and more (PBS TeacherLine, 2009).
3. Similarly, the American Museum of Natural History's Seminars on Science offer thematic six-week online science content courses with graduate credit that feature inquiry-based learning experiences and access to key scientists in content areas such as the solar system, genetics, dinosaurs, and the ocean system (American Museum of Natural History, 2009).
4. The National Science Teachers Association eMentoring for Student Success program, now called the New Science Teacher Academy (National Science Teachers Association, 2009), in partnership with the New Teacher Center at the University of California, Santa Cruz, and the Science/Math Resource Center at Montana State University offer a program whereby teachers are sponsored either by their districts or a third party organization to participate in one-one-one e-mentoring and small group discussions within same state cohorts of like-minded middle and high school educator communities during their early careers as novice teachers. The goal is to increase access to online

resources and improve pedagogical strategies and content knowledge via online professional development (Dede, 2006b). In the first year of the program, a third party evaluation conducted by Horizons Research, Inc. reported that overall participants were pleased with the experience, felt part of a community, and showed significant gains in self-confidence attributed to being part of the e-mentoring academy (Horizon Research, 2008).

5. The “Learning through Enacted Innovation” professional development approach utilizes a curriculum implementation model that involves an immersive 3-D gaming environment for students called the Quest Atlantis Project (Indiana University School of Education, 2009), where students challenge conceptual understandings through both formal and informal real-world inquiry experiences that involve reflection and discourse (Dede, 2006b). The project incorporates teacher review of student work and embeds the professional development as part of teachers’ daily routines, which includes electronic networking, review of online case videos, and school-based discussions. A new body of research is beginning to look at the richness of immersive environments given their potential to facilitate knowledge as learners navigate through virtual scenarios, apply rules of engagement, critical thinking, and problem solving through iterative levels of increasing complexity (Federation of American Scientists, 2006). Others are also researching immersive environments and their potential for deep learning (Dede, et al., 2009).

This brief case review represents a cross-section of: (a) the different types of delivery options available for online PD, (b) the different implementation models possible for online PD, and (c) the different content areas supported within the current landscape of online professional development for upper elementary and middle level science education. One tangential trend not discussed within this question is that of blending face-to-face and online learning, which is highlighted in great detail in prelim question two, and as such is omitted for discussion herein. If the case studies above in online PD are the focal point in our professional development landscape, the in-depth look below at the research themes and selected studies in online PD will serve as our “red” stylistic highlight as we continue to add in more detail and color to our canvas.

Research in oTPD in Science Education

Building conceptual understanding in any field, including science education and online professional development of the same, necessitates the review of prior empirical research, which should include the application, expansion and retraction of existing models, tools, classifications, and concepts as theories are discarded, refined and expanded. It is this process that ultimately contributes to development of tenable theories that may be used to provide explanatory and predictive power of phenomena in question that ultimately build knowledge in the field (Dede, et al., 2009; Lawson, 1995). In an attempt to provide a concise and cogent review of the literature of online teacher professional development in science education, building in part upon the work and classification scheme of prior research is not only efficacious but essential. The review that follows will build upon a recent analysis of over 400 oTPD studies (Dede, 2006a).

In seeking to include only those peer-reviewed articles that held to the most stringent standards of empirical research, Dede et al. (2009) applied the following section criteria to identify 40 studies for analysis: (a) clear and focused research question(s), (b) rigorous methods of data collection that were connected to the research questions, (c) analyses that were framed by the research questions, and (d) findings that emerged from the analysis and provided answers to the research questions. Once the 40 studies were reviewed, four general thematic areas of the research were identified to classify the current findings: (a) program design, (b) program effectiveness, (c) program technical design, (d) and learner interactions (Dede, et al., 2009). Program design studies evaluate the key salient features of a program (e.g., content, method of delivery, delivery strategies, and best practices). Program effectiveness as described by Dede (2009) look at areas that Guskey's (2000) PD evaluation model would classify as: (a) participants' reactions, and (b) learning and application of knowledge, skills and attitudes in the classroom, with the ultimate goal of increasing student learning.

The third theme, program technical design, classified studies that focused on the leveraging and alignment of the unique attributes of media with various pedagogical approaches for specific interactions, like those of building community (Dede, et al., 2009; Mentis, 2008; Oliver, et al., 2007). This theme resonates with other researchers in distanced-based learning that espouse the importance of aligning the attributes of the media, delivery modes and instructional methodologies to maximize the probability for online learning to occur (T. Anderson, 2003; Gibbs & Gosper, 2006; Harlen & Doubler, 2004, 2007; Head, et al., 2002; Weston & Cranton, 1986).

Learner interaction, the last of the four major themes for online professional development focuses on the quality of personal interaction between learner-learner, leaner-content, and learner-instructor, including the levels of support or scaffolding provided for online learners (T. Anderson, 2003; Dede, et al., 2009; McLoughlin, 2002). For years those in the distance education literature have discussed theories and moderation techniques regarding the importance of social discourse and interaction, citing it as a key feature of online learning, which when appropriately addressed, can ameliorate the *transactional* distance inherently prevalent when learners and teachers are separated in time and space (Gunawardena & Zittle, 1997; Moore, 1993; Wolcott, 1997). This theme resonates with prior and recent literature from the distance education and e-learning arena that describe and recommend the types and purposes of interaction and support available online (del Valle & Duffy, 2009; Gibbs & Gosper, 2006; McInnerney & Roberts, 2004; McLoughlin, 2002; Parker, 1999; Wagner, 1997; Weston & Cranton, 1986; Wolcott, 1997). Other areas within this theme stress the importance of understanding the contextual and social environment of the adult learner participating in online learning with the goal of incorporating authentic and relevant experiences and social discourse between learners and instructors (Cereijo, 2006; Dennen, et al., 2007; Duff & Quinn, 2006; Gibson, 1993; Kupczynski, et al., 2008; Liu, Gomez, Khan, & Cherng-Jyh, 2007; Maor & Volet, 2007; Oliver, et al., 2007). A recent meta-analysis of the comparative distance education literature evaluating over 230 studies from the periods of 1985 to 2002 state one of their conclusions with respect to social discourse:

> Distance education should not be a solitary experience, as it often was in the era of correspondence education. Instructionally relevant contact with instructors and peers is not only desirable, it is probably necessary for creating learning environments that lead to desirable achievement gains and general satisfaction with DE. This is not a particular revelation, but it is an important aspect of quality course design that should not be neglected or compromised (Bernard, et al., 2004, p. 412).

Other reviews of the literature concerning online professional development, such as that by Harlen and Doubler (2007), corroborate Dede’s (2009) four major themes of research in online professional development. In the review by Harlen et al. (2007), they focused on illuminating how online learning was being used in helping teacher practice and categorized the literature into three major research themes: (a) course design, development, online pedagogy and evaluation; (b) process of online learning including teachers perceptions and participation; and (c) outcomes of online professional development. The overlap and consistency of the research themes Dede et al. (2009) posit appear stable and reinforced by the literature in the filed of distanced education. In closing, the studies selected for review from Dede's (2006b) research are of sufficient breadth and depth across all four themes just enumerated, address in-service upper elementary and middle level education (e.g., inclusive of grades 4-8), and have been updated since Dede et al.'s (2009) review. It should also be noted that studies below are not meant to be an exhaustive list, but selected to convey a cross-section analysis in the area of science education. Other studies in PD and online PD are highlighted in prelim questions two and four as appropriate for their respective discussion. In reviewing the nine professional development studies, they coalesced into three broad categories: (a) large scale programs or meta-analysis of program impact; (b) online moderated course studies; and (c) self-paced learning, online modules or repositories.

Large Scale Programs or Meta-Analysis of Program Impact

Probably one of the most recent large scale studies that begins to address Borko's "Phase III" level of PD research (2004, p. 11) is that of Asbelle-Clark and Rowe (2007), which was a mixed method one year longitudinal study across 40 online science courses for K-12 teachers looking into the nature of communication between instructors and students, as well as the type of instructional materials and support provided. The 5-17 week courses were offered by six programs that included both non-profit and university entities, with the majority of courses being between 12 and 14 weeks in duration (67 %) and offering 3 hours of graduate credit. In two instances the courses were part of a larger online master's degree, and approximately 32 % of the courses were delivered over the span of 5 to 6 weeks, with a total of 35 different instructors across all courses (Asbell-Clarke & Rowe, 2007). Science content areas included all the science disciplines with offerings in Earth and space science, life science, and physical science; nine courses focused at the elementary level. Across the entire review nearly 800 students attended with a 90% completion rate, which led to 296 students that completed both the pre- and post-study questionnaires (Asbell-Clarke & Rowe, 2007). Some caution should be applied when reviewing the findings as they may be positively skewed given a higher percentage of those receiving an "A" grade completed the questionnaires as compared to those who received lower grades. With respect to instructional methods, hands-on activities were very rarely used across all courses (i.e., 1-2 % of the time), while hard-copy books were reported as a major resource material, with approximately 55% of the professors reporting its use between 1 and 3+ times a week (Asbell-Clarke & Rowe, 2007). Interestingly, calculators were the least often reported resource behind paper and pencil worksheets, being cited for use only 20% of the time. As anticipated, minds-on instructional methods through the use of the asynchronous moderated discussion was the most often used method with 95% of the instructors using it at least once a week, primarily for teachers to share and comment upon their own and their colleagues' understanding of scientific ideas (Asbell-Clarke & Rowe, 2007). Collaborative instructional methods, such as group projects, occurred on average once or twice during the entire course, with most small group collaboration occurring via asynchronous discussion initiated by the course instructors (Asbell-Clarke & Rowe, 2007). While course completion rates were high, and a majority of students expressed high levels of student support, no attempt was made to query those that did not complete the courses, thus potentially skewing the findings toward those with proclivities to the content or this method of learning, so caution should be applied in generalizing findings across all online PD (Asbell-Clarke & Rowe, 2007). Asbell-Clarke and Rowe (2007) conclude with a discussion of the benefit of asynchronous communication to support metacognitive reflection, but also offer the following:

> Interestingly, the use of other online technologies such as simulations, visualizations, and interactives are relatively absent from these courses. The promise of re-usable learning objects does not seem to have become a reality in this setting, and also notably missing are frequent hands-on activities. 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 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 then 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 professional development. For a comparison of this large scale study and the meta-analysis that follows, please see Table 1 for a comparison of content, PD models employed, and target audience referenced by each study.

The following three large scale studies are grouped together by the following unifying characteristics: (a) they are quantitative nature, (b) they look across different professional development programs and their impact on teacher perception or student achievement, and (c) they provide some measure of generalizability of the comparative characteristics of effective professional development called for in the research (Banilower, et al., 2007; Garet, et al., 2001; Yoon, et al., 2008). Although, the professional development programs reviewed were either administered by the original developers or evaluators, or unspecified, thus failing to meet the highest level of phase III research outlined in Borko (2004).What is also common across all three large studies is that the reviews include only face-to-face professional development models, which highlights the paucity of research in large scale online professional development, and the opportunity to begin considering how online professional development might enhance or facilitate face-to-face efforts in a blended approach to learning (Berger, Eylon, & Bagno, 2008; Kim, et al., 2008). That said, they are included herein given the aggregate findings seem to indicate some similar patterns, and as such, have implications for either online variants or blended professional development models:

1. Garet, Porter, Desimone, Birman and Yoon (2001) found the span of time over which PD occurs and the total number of contact hours has “substantial positive influence” on the quality and impact of the professional development experience. Also PD that focuses on increasing both teachers content knowledge and skills through active learning (e.g., meaningful school-based team discussions and planning involving review of student learning, classroom observations of self and others, and sharing knowledge through presentations and written work), and that is coherent (e.g., connected to other

PD experiences, is aligned to standards and assessments, and fosters professional communication), have a substantial and positive impact on changing teachers’ practices in the classroom (Garet, et al., 2001).

2. As reported by Banilower, Heck, and Weiss (2007), professional development that provides a threshold of 30 hours and up to at least 80 hours of professional development appears to be positively correlated with: (a) teachers’ perception of increased content knowledge, (b) teacher’s perception of improved inquiry-based pedagogical skills, and (c) an increased amount of time spent implementing standards-based curriculum tied to reform-based PD (Banilower, et al., 2007).
3. Yoon, Duncan, Lee and Shapley (2008) conducted a comparative quantitative analysis, or what might be classified as a “pseudo” meta-analysis as they employed the selection criteria of the “What Works” Clearing House, which ultimately permitted inclusion of 9 studies for review from an initial search pool of over 1,300 (US Department of Education, et al., 2007; Yoon, et al., 2008). While comparisons of specific features of professional development could not be compared across the selected studies, of the nine elementary studies selected for review, only one study focused entirely on science, that of Marek and Methven (1991), which was published through peer-review. Using a quasi-experimental method Marek et al. (1991) found that students of teachers using a learning cycle approach, acquired through 100 hours of summer PD, compared with students of teachers using traditional lecture-demonstration-lab modes of teaching, show significant gains in conservsation

> reasoning ability related to liquid, weight, and length, as well as the ability to use language to describe properties of matter. Generalizable findings across all PD studies by Yoon et al. (US Department of Education, et al., 2007; 2008) confirm prior research regarding the number of contact hours to make a change in teachers' practices (i.e., 50 to 80 hours of contact time), and found a moderate positive effect on student achievement of 21 percentile points compared against teachers who did not receive professional development.

It would seem across these studies that the following features are components of effective PD: (a) 50-80 contact hours of PD to affect a change in practice, (b) PD that is linked to school-wide participation or school-based teams, (c) PD that involves the review of student data, (d) PD that involves active engagement of content and pedagogical content knowledge.

Online Moderated Course Studies

The next set of studies, while not large scale do provide insight into the areas of research called for by Asbell-Clarke et al. (2007) regarding: (a) the use of hands-on learning within online science courses (Harlen & Doubler, 2004), (b) more in-depth analysis of asynchronous discussion (Lowes, Peiyi, & Yan, 2007), and (c) the use of learning objects within online science education PD (Sherman, Byers, & Rapp, 2008). Table 1 provides a high level comparison of these studies for review. The first study conducted by Harlen and Doubler (2004) designed and delivered a 13-week online course for elementary and middle school teachers of science and ran it in near parallel with a face-to-face counterpart, not to compare the effectiveness of one delivery method to another, but to discern which features might inform the design of the other. With 15 students online and 18 students on-campus, beyond typical small group asynchronous discussions, the unique aspects of the online course were: (a) the co-instruction of the course by both a science content expert and a skilled educator to help facilitate content knowledge and classroom pedagogy, (b) the inclusion of hands-on inquiry activities coupled with asynchronous discussion to increase science content knowledge, (c) a shift in the last half of the course to discuss inquiry-based learning strategies with a lesson plan project as a culminating experience to demonstrate pedagogical content knowledge (Harlen & Doubler, 2004). For brevity's sake, the face-to-face (f2f) component of the research will be of limited discussion, albeit to state that as delivered, the face-to-face synchronous course provided a less structured opportunity for reflection compared with its online counterpart. The most important course component as expressed by participants from both the online and on-site courses was the use of hands-on inquiry to learn science content, with the online group highly responsive to structured group work to learn about each others' ideas. When compared to the face-to-face participants, the following differences were reported for the online learners, who: (a) spent more time overall on the coursework, (b) expressed higher confidence in their ability to teach via inquiry, and (c) achieved a greater understanding of the science content as measured using an open response "thought experiment" written examination (Harlen & Doubler, 2004, p. 1252). Interestingly, Harlen et al. (2004) report there was little change in all participants' understandings of inquiry from pre- and post-course definitions and the final participant lesson plan. The researchers reported that the lesson plans "fell short of expectations" with respect to teachers investigating their own questions and applying concepts for both f2f and online groups (Harlen & Doubler, 2004, p. 1263). It would appear that hands-on inquiry may be a viable method to facilitate learning science content online, but care should be taken given the study was not a randomized sample, thus limiting generalizability. Additionally, it was also reported that the online instructors spent upwards of 16 % more time in moderating and engaging students online, so attribution of the findings in comparison to its face-to-face counterpart should be done with caution. Other researchers that examine the effectiveness of combining both content knowledge and pedagogical content knowledge in online courses find positive results and favorable teacher attitudes toward this course design, with the challenge being the right mix and integration of both content knowledge and pedagogical application for the classroom (Hovermill & Crites, 2008).

A recent study by Lowes, Lin, and Wang (2007) provide a detailed review of various ways to analyze teachers discourse in asynchronous discussions. Lowes et al. (2007) looked at a four week online PD course for teachers in grades 6-10 that provided information concerning programmatic details on school reform and utilized four different methods of discourse analysis to compare their utility and time investment for dissecting online discussions. In the content analysis method Lowes et al. (2007) gleaned valuable insight week by week as to the type of content responses, and using a derivative classification scheme from prior research, they coded all responses as either cheerleading/affirming, new information, or questioning/challenging. Results showed that cheerleading coupled with new information significantly increased user responses. They concluded that Blackboard's discussion reports tool was woefully inadequate, and the social networking tabular analysis method, which compared density (i.e., volume between participants), network centralization (i.e., foci of postings), sharing (i.e., volume by participant as percentage of total postings), and reciprocity (i.e., returned responses), was an expedient and insightful analysis method providing the greatest return for investment in time on a weekly basis. The content discourse analysis method, while very insightful and highly correlated to user satisfaction ratings, was also extremely labor intensive for even the small number of course participants in this study (Lowes, et al., 2007).

Finally, in a three district pilot study by the National Science Teachers Association in exploring the impact of on-demand interactive learning objects in force and motion, 45 teachers from three districts participated, with two district models occurring entirely online, and a third incorporating learning objects 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 in-tact non-randomized volunteer groups from each district, so generalizability is limited. The purpose of the pilot was to provide feedback on the initial design of the learning objects potential, to measure increases in teacher science content knowledge after working through the content, and to measure teachers' perceived confidence levels after completing the material (Sherman, et al., 2008).

Results show 91.1% of all participants completed all learning objects provided, which included passing the embedded final assessment with a score of 70% or higher. Analysis of the pre- and post-test results revealed significant gains in learning for teachers participating in the two "completely online" cohorts. The blended professional development model, which had the most contact hours did not show significant teachers gains in teacher content knowledge, with possible reasons cited for these findings. With respect to self-confidence levels as measured by a pre- and post-survey that allowed participants to rate their confidence between "not confident" to "very confident," prior to completing the learning objects, 28.9% of all participants reported they were "not confident" in the area of force and motion, and 6.7% reported they were very confident, while after completing the learning objects these percentages showed 0% participants reporting "not confident" and 60% reporting they were very confident in the topic of force and motion (Sherman, et al., 2008, p. 28). Lastly, 95.6% of all participants either agreed or strongly agreed they would recommend the learning objects to their colleagues, and 97.8% either agreed or strongly agreed that the “embedded interactions (simulations/animations) were effective in helping [their] understanding of the concepts” (Sherman, et al., 2008, p. 29).

The researchers find the overall results encouraging, but caution that while increased confidence levels and growth in content knowledge are favorable outcomes the study did not determine if these increased confidence and knowledge levels resulted in teachers changing their classroom practices. Similarly, it was found that teachers may perceive an increased confidence level in their acquisition of knowledge after receiving PD, when in fact little growth may have actually occurred; this was the case for one district’s aggregate findings. This phenomenon regarding self-efficacy and beliefs is addressed in greater detail in prelim question three discussing pedagogical content knowledge and in question four regarding one of the variables measured in determining the worth of professional development. This study does lend some credence to the notion of exploring interactive on-demand learning objects in science education PD as part of online moderated discussions (Asbell-Clarke & Rowe, 2007). It is also is part of growing body of literature regarding e-learning, that is also beginning to explore the potential of learning objects for: (a) student and teacher learning at K-8 grade levels (Downing & Holtz, 2008; Kay & Knaack, 2008; Walker, et al., 2008), (b) inquiry-based learning object design templates (Poldoja, Teemu, Valjataga, Antti, & Marjo, 2006), and (c) interoperable open systems to aid in learning object construction and sharing (Downing & Holtz, 2008; Turker, Gorgun, & Owen, 2006). While this review highlights but one study regarding the interaction between learners and content in online PD, prelim question two provides additional discussion concerning the potential of learning objects.

Self-Paced Learning, Online Modules or Repositories

In a recent review of the literature in online professional development two recent studies reveal research that is also looking at on-demand professional development for adults that is not confined to the fixed stop and start time of “traditional” online courses (del Valle & Duffy, 2009; Rhode, 2009). In a study involving 59 in-service 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 et al. (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” (p. 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 timeframes (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. Del Valle et al. (2009) did report two significant difference findings: (a) the minimalist cluster preferred to learn via cohort approach, and (b) the mastery group had significantly more years teaching experience then the task focused group. These findings differ from prior research that used brief clinical trials assigning search-oriented tasks versus this study, which used an extended timeframe 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 that looked at online learner engagement tend to find similar grouping 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).

A final study looking at self-paced online learning is that by Rhode (2009) who 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 then 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, et al., 2007; Jiang, et al., 2006; Kupczynski, et al., 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 (Duagherty, Lee, Gangadharbatla, Kim, & Outhavong, 2005). This may corroborate with those learners described by del Valle et al. (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, Bonk, Magjuka, Liu, & Lee, 2005) . 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, Straley, Shafer, & Osborn, 2009). Interestingly, while research by Hur and Brush (2009) document the socialization, camaraderie and exchange of ideas as primary reasons for teachers voluntary participating in online communities, others find educator participation in large communities challenging to sustain (Barab, The ILF Design Team, Makinster, Moore, & Cunningham, 2001; Schlager & Fusco, 2003), or start from scratch (Oliver, et al., 2007). This should provide a current cross section review of both large scale online and face-to-face PD studies involving upper elementary and middle level science education, and the varied areas being researched in the literature.

While room limits a rich discussion, a single caveat will include an additional theme from the distance education literature, that of participant drop out rate, which may be especially high in self-paced learning environments (e.g., 50% to 75%), and is traditionally higher in online learning where open enrollment is permitted (e.g., community colleges) as compared to face-to-face experiences, given some students require additional structure, scaffolding, or the camaraderie of fellow learners (Duff & Quinn, 2006; Fern University, 2003; Rhode, 2009). Work has been done to catalog reasons for attrition that may involve the following: (a) personal reasons such as lack of time, (b) learner motivation, (c) technology hurdles, (d) poor course design or delivery, (e) initial isolation of learner, (f) unresponsive feedback, (g) lack of incentives or accountability, and (h) lack of institutional support (Aragon & Johnson, 2008; Fern

University, 2003; Jun, 2005; McInnerney & Roberts, 2004). Suffice it to say, course retention strategies are essential to all online learning PD efforts and are discussed in more detail in prelim question two on e-learning opportunities within blended learning. This section will close with a look at the future development of research for online professional development.

Future Development of oTPD for Science Teachers

A review of the literature regarding the evaluation of professional development, including that of science education, appear to espouse a movement away from individual case studies and purely qualitative research, stating a major limiting factor is that its findings fail to be generalizable across large groups (Dede, et al., 2009; Guskey, 2000; Hewson, 2007; Wilson, et al., 2002). When one considers the sheer number of elementary teachers that need professional development as stated earlier, reaching 1.7 million teachers of science in the United States, this would seem to support this argument. As Hewson (2007) comments about the nature of qualitative research, "although [it] leads to a rich, nuanced description of a teacher and a deep understanding of the complexities of his or her world, it does not provide pictures of the breadth, extent, and variations of teachers' professional development experiences across schools, districts, regions, or nations" (p. 1200). Guskey (2000) corroborates this point acknowledging the limited impact of case studies, stating they typically document what is occurring in a single setting, but "the generalizability of their finings is always questionable" (p. 35). Wilson (2002) supplies an explanation for the volume of qualitative research, which in part go back to the original work of Shulman (1986, 1987), who in attempting to move the de-contextualized process-product research of the 1960s and 1970's in a more informative direction, made a strong case for using the qualitative case approach. As Wilson et al. (2002) clarifies:

> A decade or two ago, naturalistic or interpretivist inquiry was too seldom found in journals. Its growth has contributed many insights into education, schooling, and teacher preparation. It seems, however, that the pendulum might have swung too far. We found that most scholarship [regarding teacher education] was limited to small-scale interpretivist research (p. 202).

Guskey (2000) recommends a mixed method approach incorporating both quantitative and qualitative data for evaluating the impact and research in professional development. He and other researchers (Borko, 2004; Dede, 2006b; Dede, et al., 2009; Hewson, 2007; Wilson, et al., 2002) suggest using an analysis of multiple cases of professional development, and larger numbers of participants across diverse settings and varied contexts permitting , as Guskey (2000) says, an analysis of “the dynamic influences of specific elements within a context” as well as across different contexts (p. 35). Guskey (2000) makes the distinction that this method of research is different from, and may be more insightful then, meta-analysis that look at only main effects, claiming that because of its reductionist nature and approach, eliminate significant amounts of worthwhile information.

Borko (2004) maps a terrain for future professional development research methods within a three phase framework to support his analysis of the existing PD research landscape and to guide recommendations for the type of research analysis needed to address scale while sustaining quality. Most research to date, Borko (2004) claims fall into the phase I category, which looks only at an individual program and its effects on teachers at local sites. Replicability and generalizability is found wanting and does not inform policy and decision makers about the worth of the program, or its potential effectiveness for their local context (Borko, 2004). Phase II research expands this view, making the unit of analysis a review of a PD program as implemented across multiple sites and enacted by different facilitators, thus informing research and PD designers of the program's impact, replicability, and fidelity potential across diverse contexts and implementers. When Borko (2004) conducted his review for this work, very few studies were classified in the phase II category. Finally, phase III programmatic PD research, which cumulatively builds from phase II , enables comparison between PD programs, as multiple programs are deployed by multiple facilitators across a range of sites, which Borko (2004) posits, permits policy decisions regarding allocation and worth given limited resources. At the time of this research, Borko (2004) knew of no PD research being conducted at this level, and while acknowledging the value and preponderance of Phase I research, called for more studies at phase II and phase III. In a recent review of the literature of online professional development, Whitehouse (2006) also stated that while research methods have now expanded to support both quantitative and qualitative measures as espoused by those above, "most studies are still on a very small scale and not robustly generalizable across contexts" (p. 26). Finally, and most recently, after a comprehensive review of the online teacher professional development literature Dede (2009) identifies gaps in the theoretical knowledge base and elaborates on inconsistencies and dated research methods, designs, and measures for oTPD. His work will be expanded below and conclude our discussion of the areas for future research in the field of science education professional development.

Dede et al. (2009) argue that significant challenges exist in evaluating online professional development where technology is advancing so rapidly it works in opposition to the typical lead times and existing evaluation protocols used for analysis. In addition, current evaluation methods are ill-suited to answer the much needed questions of why and how online an PD model works, and how can it be formatively improved over time (Dede, et al., 2009). Given the suite of tools, interaction, and immersive features now available to the field of online teacher professional development Dede (2009) calls for a consolidated research agenda that incorporates new methods combining research and evaluation. In Dede's (2009) lament regarding the current state of affairs, he offers the following recommendations that should accompany all future research projects: (a) employ clear research questions, (b) provide definitions of all terminology and assumptions, (c) incorporate new outcome measures that lend explanatory insight into the effects of PD beyond those pervasive in current literature (e.g., self-report and standardized test scores), and (d) vary the timing and duration of measures to provide a longitudinal view of the impact of professional development experiences. He goes on to cite a list of common research practices that those in online professional development should follow: (a) build upon previous research and seek collaboration efforts, (b) utilize available data streams provided by online systems (e.g., web logs, discursive analysis, and click-stream footprints), (c) seek input from research in other domains outside of our primary field, and (d) reflect and build upon conceptual models to lend explanatory power to a growing and usable knowledgebase in online teacher professional development (Dede, et al., 2009). In closing this discussion, I concur with Dede's (2009) suggested research agenda that looks across the following areas for online teacher PD (condensed herein):

1. Research questions should be explicit, and address lasting and transformable teacher change that determines its effects on student learning, while also being scalable and sustainable.
2. Research strategies and designs should leverage existing systems and combine both research and evaluation.

3. Research models should employ more formative approaches, as well as summative and mixed method approaches to balance and inform research, evaluation, and development.
4. Research designs should include assumptions and operational definitions, and look to move beyond small scale deployments, but instead focus on flexible designs that and generalizable across varied content areas and teacher learning goals.

In closing, online teacher professional development is an exciting field of research given its plethora of tools, strategies, delivery systems, instructional design methods, conceptual models, and developmental theories that support its continued development. This discussion provides a broad stroke view of the professional development landscape, with a comprehensive, though not exhaustive, analysis of online teacher professional development by reviewing selected case studies and current research themes in online PD. Finally, a selection of oTPD studies provides illustrative detail and color in the area upper elementary science education. The challenge ahead for future researchers lies in traversing this yet uncharted territory of online teacher professional development in a systematic and empirical way, given the diversity of ecosystems that lie within its vast region. It is hoped this landscape painting of online teacher PD may serve as a navigational map for future researchers.

Table 1

Review and Description of Professional Development Studies

Research or Case Study	PD Program Delivery Model	Target Audience/ Content Area
	Large Scale Programs or Meta-Analysis Studies	
Asbell-Clarke et al. (2007)	40 online short courses from 3 non-profits and 3 universities	middle and high school science
Banilower et al. (2008)	local systemic change, reform-based PD	elementary and middle science
Garet et al. (2001)	Eisenhower PD program, traditional and reform-based professional development	elementary, middle and high, mathematics and science
Yoon et al. (2008)	summer institutes, some with follow-up	elementary, English/language arts, mathematics, and science
	Online Moderated Course Studies	
Harlen et al. (2004)	online short course with hands-on	elementary and middle science and inquiry
Lowes et al. (2007)	online short course using discussion	middle and high school, reform integration focus
	Self-paced Learning, Online Modules or Repositories	
del Valle et al. (2009)	self-paced, on-demand, instructor support	elementary, inquiry and technology integration
Rhode, J. (2009)	self-paced, on-demand, instructor support	undergraduate courses with adult learners, technology integration
Sherman et al. (2008)	on-demand learning objects with e-mentor	middle school science and inquiry
	Case Studies in Online Professional Development	
EdTech Leaders Online	online short courses, states & districts design	elementary, middle, high, math, science, social studies, English
PBS TeacherLine	online short courses, moderated	elementary, middle, high, math, reading, science, technology, pedagogy
AMNH Seminars on Science	online short courses, moderated	grade level unspecified, science themes, e.g., genetics, sharks
NSTA e-Mentoring	self-paced, on-demand, e-mentor support	middle and high school, science, physical, Earth & space, and life
Quest Atlantis	Immersive student game, school reform	upper elementary, middle school science life science

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