Question 2: A conflict with what many people believe to be essential, hands-on learning, with what appears to be necessary in a limited (tight) fiscal situation, scale may be amenable to technological solutions. What does the literature say about such cases. Off the top of my head I'm thinking about everything from "can't be done," to blended instruction, to virtual manipulation and everything in between. Summarize with your sense of the tradeoffs that must be made for each solution.

As discussed in the question concerning online teacher professional development (oTPD), current large scale empirically driven research and evaluation studies looking at sustainable, scalable, and replicable PD models (face-to-face, blended, or online) are just beginning to emerge based on the recommendations of numerous researchers in the field (Borko, 2004; Dede, Ketelhut, Whitehouse, Briet, & McCloskey, 2009; Guskey, 2000). Currently, the lion's share of existing oTPD opportunities take the form of moderated online courses (The Sloan Consortium, 2008). Juxtapose this against what the research calls for in terms of high quality professional development, which was discussed in the question regarding the same, and one notices very little mention in terms of online offerings or their validity. For example, all the professional development studies cited in Hewson (2007) omitted the inclusion of any online or blended PD models. Similarly, in reviewing the large scale PD studies that looked at the Eisenhower PD programs (Garet, Porter, Desimone, Birman, & Yoon, 2001), the National Science Foundation (NSF) Local Systemic Change efforts (Banilower, Heck, & Weiss, 2007), and in the large scale review of studies by Yoon, Duncan, Lee and Shapley (US Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, & Regional Educational Laboratory Southwest, 2007; 2008), all conspicuously omit studies that are either completely online, or include online components. This observation has been buttressed by others looking into distanced delivered professional development to improve science content knowledge at the upper elementary and middle school levels (Krall, Straley, Shafer, & Osborn, 2009).

In a recent evaluation report sharing the make-up of professional development offerings of the 2005-2006 US 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 (US Department of Education, 2006). The remaining 34% of the sponsored PD programs did not provide a summer institute, but on-site professional development, study groups, university courses, as well as the inclusion of online coursework and digital learning networks, but the statistics for the proportion of each component were not disaggregated. In looking at the investment for the 2005-2006 school year, $337,015 was the average expended per program, with a mean of 113 teachers attending each program. For a total investment of $181 million dollars, roughly 56,000 teachers were impacted across 501 programs. While at first glance 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 then 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 and it would seem that an online component may provide some economies of scale from a cost effectiveness standpoint. Finally, in keeping with current theories about the nature of high quality PD, that it should be on-going, locally-based, and continuous throughout the school year (Elmore, 2004; Hawley & Valli, 1999; Loucks-Horsley, 1999; National Staff Development Council, 2008), it would seem that online learning opportunities may facilitate issues of scale, continuous support, and sustainability. This response will look at the current options available via the web for distance delivered learning, enumerating opportunities and barriers both from an individual and organizational standpoint, and summarizing the tradeoffs between each solution at the conclusion of this response.

Opportunities with e-Learning

In just the last four years, the emergence of computing platforms that are extremely powerful, extensible, portable, interoperable, and affordable have converged with ubiquitous and affordable high speed Internet access (The New Media Consortium & EDUCAUSE Learning Initiative, 2009). Couple this with user-driven web collaboration tools (McLoughlin & Lee, 2008a), the information tsunami accessible via the Internet, immersive virtual gaming environments (Federation of American Scientists, 2006), and mobile on-location GPS technology overlaid with remote sensing visualization (The Education Arcade, 2009), and one begins to see the flashpoint for catalytic ideas focused on education applications that may be harnessed for science education. These developments afford a wide range of opportunities for e-learning in science education professional development, but also present impediments and barriers to overcome for their effective implementation. Downing and Holtz (2008) reviewed the landscape of science and science education online and provide a comprehensive listing of initiatives and opportunities available, which in part will provide the organizing topics to guide this review with the caveat that several categories have been collapsed for brevity’s sake: (a) virtual and remote labs, simulations, and hands-on learning; (b) learning objects, repositories, and digital libraries; (c) online games and immersive environments; (d) blended professional development solutions for science education; (e) mobile access, probes, and GPS technology convergence.

Virtual and Remote Labs, Simulations, and Hands-on Learning

Laboratory activities at the high school level and hands-on inquiry investigations across the K-12 level, whether real or simulated via technology-enabled solutions, are critical to the process of learning science in the 21^{st} century (American Association for the Advancement of Science, 1993; National Research Council, 1996, 2000, 2007; National Research Council & Committee on High School Science Laboratories: Role and Vision, 2005). Given the challenges of scale and opportunities potentially afforded via online professional development discussed above, how might these experiences fare online? A growing body of literature at the undergraduate level and a few studies at the K-12 level are emerging in science education (d'Ham, Vries, Girault, & Marzin, 2004; Downing & Holtz, 2008; Harlen & Doubler, 2004; Krall, et al., 2009; Ma & Nickerson, 2006; Scanlon, Colwell, Cooper, & Di Paolo, 2004; Vogel, et al., 2006).

Hands-on learning. 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. Interestingly, while the inquiry facilitated online learning that was beneficial and effective, researchers report that teachers' overall understanding of the process of inquiry itself showed less then stellar gains as measured by pre- and post-course participant definitions of inquiry and submissions of final lesson plan projects (Harlen & Doubler, 2004). As discussed in the question regarding pedagogical content knowledge, prior experience and existing beliefs are difficult to change from a conceptual point of view. When asked to rank their preference for the most important components of the online course, seven teachers reported the use of inquiry as an instructional strategy most valuable, five cited the investigations as most important, three expressed the discussion with colleagues as most valuable, two preferred the online journal reflections, and two participants 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, Byers, & Rapp, 2008; Su, Bonk, Magjuka, Liu, & Lee, 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 and generating a higher volume of reflective statements concerning their learning then their face-to-face counterparts using physical journals.

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, Staraley, Shafer and Obsorn (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 inducement 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 1970's (Downing & Holtz, 2008). When asked to rank the importance of various components of the online course, 85% rated interaction with other local teachers and the kit materials both as the highest priority, with the lab activities and investigations to use the materials ranked second at 82%, which was then followed with 68% ranking the importance of the CD-ROM content to guide concept development third (Krall, et al., 2009). Two interesting observations were discovered. First, while not required to participate in online discussions with those in geographic proximity to each other, 40 of the 43 teachers opted to do so, and several voluntarily decided to meet face-to-face to discuss the hands-on investigations (Krall, et al., 2009). This would corroborate the importance of social collaboration in constructing knowledge via inquiry-based methods discussed in the pedagogical content knowledge and professional development preliminary exam questions. Ironically, the email support provided by the instructor was ranked as the lowest of all course components at 54%, equal to that reported for teacher reflective journals, and lower then the CD-ROM content (Krall, et al., 2009). This finding is corroborated in the self-paced PD model of Sherman, Byers and Rapp (2008). While not rated as the most valued component, one would suspect that the availability of a course instructor still plays an important role in the learning process from a scaffolding, support, and accountability perspective. These findings may be due to the actual role facilitated by the online instructor, as other studies find the instructor interaction a critical component in online learning (Dennen, Darabi, & Smith, 2007; Kupczynski, Brown, & Davis, 2008; Rhode, 2009; Sujo de Montes, 2009). While difficult to know for certain in Krall et al. (2009), given the lack of mandated weekly asynchronous discussion, the instructor's role appeared to be primarily one of review and acceptance of final work versus that of facilitating knowledge construction through online discourse. This shows the trade offs that occur when attempting to balance the needs of task focused learners who desire to proceed at their own pace (del Valle & Duffy, 2009), and those that desire a collaborative cohort approach as reflected by this study. Perhaps, as demonstrated by Rhode (2009), a rolling open monthly enrollment option with voluntary open discussion mechanisms and instructor mentor support may address this challenge. In answer to the question if hands-on inquiry-based learning is possible online, for basic investigations that do not require access to specialized equipment or instruments, it would appear so. 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. So the next question becomes, are more sophisticated inquiry or laboratory investigations possible online and if so, what does the research show regarding their effectiveness?

Virtual and remote labs, and simulations. At the high school level there has been a lack of agreement on what exactly constitutes a laboratory activity given the rapid change in technologies and evolving skills needed to be competitive the 21st century, but an emerging consensus finds laboratories are no longer confined to the walls of a specific room or set of equipment. Researchers suggest inquiries should also utilize online databases of information and experiences afforded through various remote technology (National Research Council & Committee on High School Science Laboratories: Role and Vision, 2005). In 2005 the National Research Council defined the value of lab experiences as providing “opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science” (National Research Council & Committee on High School Science Laboratories: Role and Vision, 2005, p. 3).

The report recommends goals and benefits for laboratory experiences that also cascade down to middle school grades 6-8, which include enhanced understanding of: (a) subject matter, (b) the complexity and tentativeness of science and the nature of science, and (c) the ability to design and conduct experiments that facilitate teamwork and cultivate motivation and interest in science (National Research Council & Committee on High School Science Laboratories: Role and Vision, 2005). Given this charge, how might remote or virtual labs and simulations facilitate learning science and inquiry?

Remote and virtual labs are experiences that afford an individual or group of individuals the ability to conduct a variant or close approximation of the same investigation while separated from the physical equipment at a time and place more suitable to their needs (d'Ham, et al., 2004; Downing & Holtz, 2008; Ma & Nickerson, 2006; Scanlon, et al., 2004). This is accomplished through various technologies that may include web conferencing, remote controlled cameras, robots, intelligent artificial tutors and remote human tutors. For example, Scanlon, Clowell, Cooper, and Di Paolo (2004) conducted a study between four universities whereby they permitted collaborative dyads, including students with disabilities, to synchronously execute an optical spectroscopy of sodium. By placing the lab equipment on a rotating gig, mounted with three remotely controlled cameras that captured the data results live, the geographically separated teams executed the investigation with the aid of a human tutor via live chat and web conferencing (Scanlon, et al., 2004). In constructing the remote lab, while the original intent was to replicate the experience as would be done by hand, cost considerations necessitated substituting a live flame test with pre-recorded web-accessible video equivalents. Researchers also decided to truncate calibration and equipment setup for the spectroscopy (i.e., focus of the spectrometer microscope and insertion of the diffraction grating were not automated, but manually executed for the lab students by the remote tutor), as it was deemed non-essential to the learning outcomes of the investigation (Scanlon, et al., 2004). Findings from the 12 student groups, across both those using the equipment remotely and hands-on locally revealed the following (Scanlon, et al., 2004):

1. All expressed that the value of the remote lab was preferred to a virtual simulation of the same, citing static or canned data as a drawback with simulations.
2. All admitted the remote lab was a viable alternative if physical access restricted tangible use of the equipment.
3. The students had reservations whether the system as currently designed could fully supplant the traditional laboratory experience if they were to achieve all of the original objectives of the experience.

Other limitations noted the extra time it took for the remote student groups to complete the experience, given they had to get acquainted with their remote lab partner, the tutor, and the lab procedure since the equipment was not physically in front of them (Scanlon, et al., 2004). A negotiation of the transactional distance that involves negotiating the structure of the environment, the dialogue between the learners and instructor (the tutor in this case) and the autonomy of learners, intersect within the graphical user interface that connects them to the physical and contextual environment of operating equipment and conducting the experiment (Moore, 1993). From a faculty perspective, two focus groups expressed that remote labs may: (a) be a viable alternative for those without physical access, (b) maintain its motivational potential in spite of no physical contact with lab apparatus, (c) address safety concerns in using certain chemicals, (d) have prohibitive initial set-up costs, and (e) limit skill acquisition in the handling of physical apparatus (Scanlon, et al., 2004). In conclusion, both academic focus groups did see the value remote labs could lend to the development of basic skills such as data collection, recording and observation (e.g., process skills), but identified areas where it may not be suitable in some areas of chemistry where the resolution of the remote cameras may be insufficient for the task at hand (Scanlon, et al., 2004). Conversely, there are others designing remote lab systems in chemistry that do allow student control of the conceptual design of the experiment with feedback from intelligent tutors, and relegate the tasks of pouring and measuring solutions in graduated cylinders to the exact precision afforded via robotic syringes (d'Ham, et al., 2004). Providing a concise synopsis of the intellectual value in planning and designing experiments to build conceptual content knowledge, d'Ham, Vries, Girault, and Marzin (2004) discuss the acumen afforded when students generate subtasks and investigatory steps needed to execute certain experimental procedures that are frequently used in chemistry, such as identifying the compounds in a solution. They present a remote laboratory that facilitates this process via a robot and an artificial intelligent tutor to scaffold students' steps before they execute a procedure once time is acquired on the shared remote lab platform (d'Ham, et al., 2004). While some share concerns that procedures such as this do not permit tangible access to manipulating equipment (Ma & Nickerson, 2006; Scanlon, et al., 2004), others argue access to local physical apparatus is increasingly mediated through a computer interface, thus blurring the line of the importance in physically manipulating equipment (Ma & Nickerson, 2006). One common example in science supporting the views shared in Ma and Nickerson (2006) and d'Ham et al. (2004) is in astronomy where researchers plan, design and submit investigations for approval, that upon acceptance, permit access through computer-based interfaces for both Earth-based or Earth-orbiting observatories which seek to answer some of our most fundamental questions about the universe (National Aeronautics and Space Administration, 2009).

Coming back down to Earth, there are also virtual labs and their close cousin, simulations, which vary by the degree in which learners control the environment and phenomena under investigation. In the case of multimedia simulations learners typically change the parameters of variables, run the simulation, and make observations and data analysis as they test their predictions and see the relationship between the variables under inspection (Downing & Holtz, 2008; Ma & Nickerson, 2006). In a recent comparative review of the literature beginning with over 1,000 studies, Ma et al. (2006) sought to clarify the reasons for the debate between both advocates and detractors for one form of lab over another, whether hands-on, remote, virtual or simulated. First, three overall observations were provided:

1. Most of the laboratories reviewed are in the engineering domain, with 39 studies in engineering and 13 from the sciences to comprise the final 60 that were selected for comparative analysis.
2. There are no standardized criteria to evaluate the effectiveness of labwork across reviews for the following reasons: (a) uniqueness of the topic under study, (b) varying methods used for analysis, and (c) commingling between the various types of labs. This observation was confirmed by the National Research Council as well (National Research Council & Committee on High School Science Laboratories: Role and Vision, 2005).
3. There are both advocates and detractors for each type of lab (i.e., hands-on, simulated and remote), with the general consensus finding no consistent or significant difference between them (Ma & Nickerson, 2006). This finding is in contrast to other K-12 meta-analysis studies that show simulations and computer-

based instruction improve student learning, attitudes toward learning, and efficiency in learning (Kulik, 1991; Lee, 1999; Vogel, et al., 2006).

Advocates of hands-on labs espouse the value of setting up the physical equipment and the realism afforded through unexpected surprises when theory meets authentic practice (Ma & Nickerson, 2006). A drawback though of hands-on labs is the ever increasing expense needed to maintain the space, infrastructure, and equipment. This argument posits an advantage for simulated labs, which avoid these escalating cost, while also providing the opportunity to actively engage in practice, reflection and control of the laboratory environment (Ma & Nickerson, 2006). Alternatively Ma et al. (2006) find detractors who claim a fallacy exists with purported cost savings claiming certain simulation development costs may be quite high, which even when completed, may appear surreal and disingenuous, thwarting their intended purpose. Detractors also say simulations may not permit the trial-and-error scenarios found in the physical authentic world. Ma et al.'s (2006) consensus review regarding remote labs acknowledges the potential cost savings between institutions and the educational value of collaboration between students across universities, but cautions some are wary of being lured by the glitter and promise of technology-enabled solutions, and the learning impact is yet to be demonstrated on a large scale.

In an effort to clarify the debate and move the research agenda forwarded, Ma et al. (2006) codified the studies across three purposes for laboratories as commonly presented in the literature: (a) design skills (e.g., ability to design and investigate), (b) professional skills (e.g., ability to acquire skills needed for practicing in the profession), (c) conceptual understanding (e.g., ability to solve problems related to key concepts), and (d) social skills (e.g., group teamwork facilitation). What Ma et al. (2006) conclude is that depending on one's view of the educational purpose for labs, the degree of educational criterion change, thus rendering variance in lab delivery preference due more to one's beliefs and perceptions about the value of a lab modality then its actual physical or virtual affordances. Ma et al. (2006) cites multiple research studies that claim a high transfer of learning is more associated with a high psychological perception of a lab's reality then its actual physical fidelity. They argue it may be possible to instantiate a sufficient psychological presence to accommodate the lack of a physical one that often drives up development costs. Psychological presence alone though cannot predict students' engagement and learning in virtual or simulated labs as Ma et al. (2006) posit other factors that also come into play, such as: (a) students' learning preferences and motivation, (b) peer-collaboration structure enacted, (c) the type of feedback provided, (d) and the fidelity of the environment's media.

Interestingly while the debate ensues among academics at the undergraduate level between preferred delivery medium for remote investigations, there appears to be an emerging consensus at the K-12 level in science that simulations, computer-based instruction, and real-time data analysis via graphical representations afforded via digital computer-based probes, enhances user motivation and learning (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 utilized makes a difference in their performance, 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 state the challenge of confounding variables across studies, and suggest caution in generalizing their findings, while confident in their identified trends (Lee, 1999; Vogel, et al., 2006). It should also be noted, as discussed in the other prelim questions regarding the ubiquitous use of mobile technology, online gaming, and social networking tools, that younger students are more keenly acclimated to using these emerging technologies (Cobcroft, Towers, Smith, & Axel, 2006; Federation of American Scientists, 2006; Green & McNeese, 2007), while teachers, as digital immigrants, will need the following support to effectively use technology-enabled solutions: (a) access to the equipment with stable and adequate Internet connectivity, (b) on-going professional development (e.g., not a one-shot workshop), (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). This research has implications on the use of web-enabled technology for teacher professional development from a support and implementation standpoint, as well as for decisions regarding the selection and inclusion of rich media, such as simulations, that if intended for use with students, should be embedded within the professional development (Asbell & Rowe, 2007; Linn, 2006; Varma, et al., 2008). All labs whether real, remote, or virtual, should focus on facilitating conceptual understanding, problem solving, and understanding the nature of science and inquiry, avoiding rote “cookbook” procedural methods that typically involve only verification or confirmation of prior findings and low, non-engaging cognitive skills for learning (Lunetta, et al., 2007).

In closing the discussion on the advantages and disadvantages cited between remote laboratories, virtual laboratories, and simulations, it would seem that each may have their place, but before deciding on which method to employ for online learning, a cost benefit analysis that seeks to measure the effectiveness of various technology-enabled solutions should occur to guide future decisions regarding their worth from a student learning point of view, as well as their potential scalability and sustainability (Laurillard, 2007; Marengo & Marengo, 2005; Morris, 2008; Twigg, 2003; S.-W. Yoon & Lim, 2007). While important to track the production and delivery costs for online media, for online science education courses it appears interactive simulation and lab experiences are missing from the landscape.

When comparing the literature above to that by Asbell and Rowe (2007) it would seem that there may be a disconnect, as the majority of online course instructors in science education primarily focus on asynchronous discussion as the strategy and mode for learning. While an essential part of building conceptual knowledge (see prelim questions one and three on PD and pedagogy respectively), this omits the benefits afforded by interactive technology such as simulations, and virtual labs. The following logic supports the inclusion of simulations, remote and virtual labs in teacher professional development:

1. Professional development for science teachers should include “immersion in the science content they teach, either through inquiry and problem-solving in science, or by spending time in the world of scientists” ("America Competes Act ", 2007; Hewson, 2007, p. 1187).
2. Scientists utilize technology tools such as simulations and remote and virtual labs as part of their everyday work in science (Downing & Holtz, 2008; National Science Teachers Association, 2008; Songer, 2007).
3. National professional development standards for science education state, “…a useful way to learn science content is to participate in research at a scientific laboratory” ("America Competes Act ", 2007; National Research Council, 1996,

p. 58), and remote labs afford this opportunity when physical presence is prohibited (Downing & Holtz, 2008; Scanlon, et al., 2004).

Given the logic above, it seems worthwhile to incorporate these technology-enabled opportunities and tools into online science teacher professional development (Asbell & Rowe, 2007; Dede, et al., 2009). In addition to virtual labs and simulations, another resource for interactive opportunities in e-learning is learning objects.

Learning Objects, Repositories, and Digital Libraries

Learning Objects, which may be part of a larger online digital library repository, are chunks of encapsulated learning content at various grain sizes that have been tagged using standardized schema, such as learning object metadata or Dublin Core extended metatags, which permit the auto-harvesting of descriptions about the learning chunks, as well as their import and export across different learning management systems (Downing & Holtz, 2008; Weller, 2007). The reported value of learning objects may be in their re-purposing and reuse, thus potentially affording large efficiencies in scale and scope for learning through economies in production savings, and by enabling dynamic learning paths for users as they navigate through different objects (Downing & Holtz, 2008; Laurillard, 2007; Littlejohn, Falconer, & McGill, 2008; Morris, 2008; Turker, Gorgun, & Conlan, 2006; Weller, 2007). While these advantages are often cited, detractors list the following limitations:

1. Sequencing and reuse between different learning objects, if dynamic, may facilitate a lack of context, cohesion, and narrative across the learning objects, which promotes poor learning referred to as the Frankenstein or mosaic effect (Poldoja, Teemu, Valjataga, Antti, & Marjo, 2006; Turker, et al., 2006 ; Weller, 2007).

2. Dynamic navigation between objects may permit insufficient coverage and depth of certain content (Turker, et al., 2006; Weller, 2007).
3. The on-demand nature of objects accommodate individual learner pacing preferences at the expense of collaborative group discourse and building on prior work for academic progression (Weller, 2007).
4. Difficulties in granularity, interoperability, and reuse of learning objects arising from a “not created here” perspective may limit cost savings if finding and repurposing their use is challenging (Laurillard, 2007; Morris, 2008).
5. Canned and fixed content, such as learning objects may not facilitate constructivist-based inquiry approaches or personalization of content and may bore students in light of web 2.0 technologies (Dron, 2007; McLoughlin & Lee, 2008a).

Weller (2007) credits the following reasons for the slow adoption of interactive learning objects in higher education: (a) perceived as a threat to instructors’ expertise and professionalism, (b) questions about quality given homogenization of objects, and (c) overly concerned focus on e-learning reuse weakening the integrity of the learning experience. With these challenging barriers to adoption, consideration of the benefits needs to be examined, foremost of which are the drivers of reuse and cost savings (Littlejohn, et al., 2008; Morris, 2008; Weller, 2007). The arguments concerning grain size are flexible and controlled by the designers, where “Learning Design” tools are emerging that permit the content, if parsed at an appropriate grain size, to be separated, pedagogically tagged, and reused across different pedagogies (Littlejohn, et al., 2008; Morris, 2008; Weller, 2007, p. 36). Also, as demonstrated above, learning objects that contain simulations or virtual lab-like experiences have been shown to increase the effectiveness and efficiency in certain learning situations, especially in science, where users are permitted to view and control scenarios that are otherwise challenging or impossible to visualize and manipulate. From the perspective of Asbell-Clarke et al. (2007) learning objects would appear to be a welcome addition to the current raft of online science education courses that rely heavily on asynchronous discussion and journal readings as the strategy and content for learning.

In closing the discussion on learning objects, Weller (2007) makes an observation concerning their path to widespread adoption, stating that virtual learning environments, such as Blackboard, were easily accepted given their paradigm replicated that of the traditional classroom, and while far from perfect, have laid the groundwork for the next succession of systems that need to be more flexible and open permitting the co-creation and exchange of content and pedagogical models for course design. Others are more dogmatic in their call for a more abrupt paradigm shift away from the current monolithic course management systems, calling for an open-access system that utilizes smaller interoperable tool sets and stand alone web-based modules, which will be more flexible over the long term as learning affordances change with new tools as they emerge (Dron, 2007; Jiang, Parent, & Easmond, 2006). Regardless of the position taken from the arguments above, it would seem that some variant of coherent and instructionally sound learning nuggets would conjoin and improve the existing online professional development course landscape. Having each instructor re-create materials from scratch for every course, many of whom may not have the necessary skills, money, or time to create interactive simulation-based learning objects, would seem to warrant an approach that permits content exchange and reuse (Laurillard, 2007).

Examples of portals that seek to leverage the utility of shared design and expense, such as Merlot.org (Multimedia Educational Resources for Learning and Online Teaching, 2009), allow professors to upload and share simulations and course materials. Although Merlot.org does not permit the import/export of entire learning objects or course pedagogies directly into various course management systems, it may be that an individual simulation is at the grain size professors desire as they design courses within the bounds of the creative commons license (Creative Commons, 2009). Efforts such as the National Science Digital Library (National Science Foundation, 2009), OER Commons (Open Educational Resources, 2009), and the NSTA Learning Center (National Science Teachers Association, 2009) are but a few examples where large free collections of varied media and tools are available to assist science teachers in their access to online professional development and digital resources for the classroom.

While not much has been provided herein regarding digital libraries, their clarification needs little explanation other then to say they should contain the following features: (a) be easy to use; (b) permit efficiency in quickly locating high quality resources that are age, grade, and content appropriate; and (c) provide sufficient information for ease of integration into a learning context (e.g. ideas for use, standards alignment, and technical requirements) (Downing & Holtz, 2008). Movement on this front linked with learning objects are now extending the description and classification for reuse to focus not just on what type of resource it is, but also on its value as used across different educational contexts. Littlejohn, Falconer, and McGill (2008) argue that for a resource to be effective, it needs to support all three stages of resource use, from: (a) conceptualization (e.g., sourcing new information), (b) construction (e.g., manipulation and application), and (c) integration (e.g., augmentation, annotation and sharing the resource within a larger community). Others also offer conceptual frameworks, cognitive tools, and delivery models for transforming how existing digital resources may be more effectively used for self-guided inquiry-based learning experiences (Nesbit & Winne, 2003; Songer, 2007), which appear to incorporate components of instructional systems design in their methodologies (e.g., analysis of audience, learner, and context) (Dick, Carey, & Carey, 2008). Others create repositories or CD-ROM media that deliver on-demand access to digital videos of teacher lessons being conducted in situ to stimulate teacher self-reflection and online discussion (S. Barab, The ILF Design Team, Makinster, Moore, & Cunningham, 2001; Watters & Diezmann, 2007). Issues with digital libraries may include interoperability, tagging, search and retrieve, user authentication between collections, and tools to facilitate use, but one of the major standing concerns for the National Science Digital Library is that of sustainability, as infrastructure, maintenance, currency, and innovation are costly, and reliance solely on federal grant funding is not in itself a viable long term business model (Edmonson & Morris, 2006). Digital libraries aside, one of the most popular types of online portals accessed via the Internet is multi-player online games and immersive environments, which will be briefly discussed as another possibility for online professional development.

Online Games and Immersive Environments

A new wave of research is beginning to emerge analyzing the value of immersive online environments and games, such as massive multiplayer online computer and video games, as well as brief experience games available via small portable devices, such as mobile phones or Personal Digital Assistants (PDAs) (Ang, Avni, & Zaphiris, 2008; Dickey, 2005, 2006; Federation of American Scientists, 2006; Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009). Most of the effort of late deals with: (a) recommendations for co-opting their use for K-12 education (Federation of American Scientists, 2006; Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009); (b) generating topologies and heuristic evaluation guidelines as aligned with various behaviorist, cognitivist, or constructivist learning theories (Ang, et al., 2008; The Education Arcade & Massachusetts Institute of Technology, 2009); and (c) dissecting the various features that differentiate massively multiplayer online role playing games (MMORPGs) from social learning networks (Dickey, 2005, 2006; Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009). The research and exploration of games, online or otherwise, seems worthy given there is substantive evidence that tens of millions of users across all age groups and gender are incorporating them into their daily lives (The Education Arcade & Massachusetts Institute of Technology, 2009). The statistics below show the breadth and depth of their use:

1. More then 8 in 10 young people have a video game console in their home (Federation of American Scientists, 2006).
2. Boys 8-13 years of age spend close to 50 minutes a day playing console or online games, and children between the ages of 2 and 18 years old spend 20-33 minutes per day (Green & McNeese, 2007).
3. Simple, affordable, and easily accessible game playing platforms, such as the portable handheld Nintendo DS and Nintendo Wii game console combined have sold over 100 million units as of Spring 2008 (The Education Arcade & Massachusetts Institute of Technology, 2009).
4. Mobile smart phones that can play games are growing in their ubiquity at an enormous rate, such as the iPhone, which sold over 4.3 million units in the last quarter of 2008 represented an 88% unit growth over the same quarter the prior

year (Apple Inc., 2009b). The iPhone is but one model from the 1.2 billion mobile phones available that enter the market each year (The New Media Consortium & EDUCAUSE Learning Initiative, 2009).

5. Online gaming is not just for young boys or young men, with casual gaming among women constituting over half of all online gamers and over 43 million online visitors in 2008, with the largest growth coming from females between the age spans of 12-14 and 55-64 years of age (Lipsman, 2006; Vollman, 2008).

Given their voluminous use, it seems worthwhile to explore games for their teacher learning and how games are different then, but may be combined with social networking sites, another "trend" that was discussed in the online professional development prelim question one.

Common features that make up many role playing games and what differentiate them from social networking sites include features such as: (a) definite beginning and end-points that include an overarching goal or quest for the main character to answer a call; (b) strong narrative storyline with typical arcs and patterns over the journey with hooks, back stories, and cut scenes; (c) set of rules for engagement that guide parameters of play within the environment for individual and group players; (d) positioning role of the main character within the game who traverses a series of increasing challenges, permitting experimentation, failure, and reward; (e) varied levels of interaction with non-player game objects and other players allowing users free choice and active engagement through the environment (Dickey, 2005, 2006; Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009). These features are different from social networking sites that are primarily 2-D, text-based, and include sharing of images and videos. Although, social networking sites may incorporate features of games, or link out to virtual immersive 3-D worlds, such as SecondLife, where users assume a role, but are not progressing toward a common quest with a definitive endpoint (Atkinson, 2008; The Education Arcade & Massachusetts Institute of Technology, 2009). Given the interactive features of MMORPGs, early findings posit the following advantages for game-based learning: (a) increases problem-solving, critical thinking, interpretative analysis and multi-tasking abilities; and (b) elevates a sense of motivation and accomplishment, increasing time-on-task, persistence, concentration, patience, adaptability, and collaborative teamwork (Federation of American Scientists, 2006; Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009).

While the potential for online games appears vast, educational research calls for more studies concerning their efficacy in areas such as: (a) type of game and its related interactions; (b) how games are used, within what context, and in conjunction with what other materials; and (c) type of learning achieved, whether content knowledge, critical thinking, communication, or social teamwork skills (Downing & Holtz, 2008; Federation of American Scientists, 2006; The Education Arcade & Massachusetts Institute of Technology, 2009). A long list of challenges for games as learning vehicles in formal K-12 education has also been posited:

1. Integration, impact and logistical issues are barriers that include: (a) appropriate alignment to school curriculum, content standards and assessments; (b) access to sufficient hardware for game play; and (c) fixed structure of existing school class periods that limit use for extended periods of play (Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009).
2. Other barriers include negative attitudes and hesitancy from parents, administrators, and teachers that believe many commercial games are: (a) profit centric, (b) stifle serious learning , (c) decrease learning perseverance, (d) inflict

health issues such as obesity and game addiction, and (e) fail to substantiate deep learning by not drawing on prior experiences of learners (Green & McNeese, 2007; Hew & Brush, 2006; The Education Arcade & Massachusetts Institute of Technology, 2009).

3. Initial cost of development for virtual 3-D immersive games may take several years to create and cost millions of dollars and when completed may not resonate with its intended audience or improve learning. Or, in spite of quality, have a short lifespan given the rapid change in technology and the fickle nature of users (Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009).
4. Lack of teacher familiarization with technology and access to appropriate hardware for on-going professional development to facilitate classroom integration are barriers that may ultimately result in teacher frustration and non-use of the technology altogether (Hew & Brush, 2006; Hofer & Swan, 2008; Linn, 2006; Overbaugh & Lu, 2008; Varma, et al., 2008).

Rebuttal to these impediments suggest the following alternatives to advance implementation and decrease development costs: (a) support game use out of school, saving classroom time for discussion and group data analysis; (b) utilize short duration games and ones available via mobile technology, thus alleviating access issues; (c) leverage existing commercial games for learning with supplementary scaffold materials such as curriculum integration guides; (d) share core runtime engines, assets, and characters to leverage reuse of gaming components, thus decreasing development time and costs for larger 3-D immersive gaming environments (Green & McNeese, 2007; The Education Arcade & Massachusetts Institute of Technology, 2009). While this review discusses challenges for implementation of immersive online environments and games in classroom settings, the same issues apply if used for professional development. Also, as previously discussed in the question regarding online professional development for teachers, and later in this response, one of the primary challenges adults face in their own professional development is that of securing sufficient time for learning. While brief duration games may fit within an adult's hectic schedule, online immersive games, as currently structured, are not designed to be completed expeditiously, but over time, through increasing levels of challenges and complexity, which may not align with teachers' preferences for learning, or time allotments for professional development. With a pro and con review of the value of games and online immersive environments discussed, perhaps more of a blended solution to professional development is what is needed.

Blended Professional Development Solutions

Blended learning, while not cited as an emergent trend in science education professional development, in the sector of higher education and corporate training, it is a sleeping giant (Kim, Bonk, & Oh, 2008; Vaughan, 2007). In reviewing the literature, many definitions for blended learning have been offered which vary in their focus and emphasis, but all ultimately describe a mix between face-to-face and online learning. Organizations deploy a wide variety of blended learning solutions, each of which incorporate various media, methods, strategies, and models of delivery (Kim, et al., 2008; Smith & Kurthen, 2007; Tang & Byrne, 2007; Vaughan, 2007; Verkroost, Meijerink, Lintsen, & Veen, 2008; S.-W. Yoon & Lim, 2007). Simply said, blended learning involves the mix of pedagogical methods in combination with various learning strategies that seek to involve various degrees of technology-mediated solutions to maximize desired learning outcomes (Verkroost, et al., 2008). In conducting an international survey and review of blended solutions Kim, Bonk, and Oh (2008) cite the following different models for blended delivery: (a) anchor blend (i.e., begins with classroom instruction then continues online); (b) bookend blend (i.e., online occurs both before and after the live session); and (c) field blend (i.e., access to online resources when and where needed with face-to-face follow-up as part of a sequence or culminating experience). Kim et al. (2008) suggest that the field blend is the most learner-centered and most flexible of the three models, but state it also is the least structured, which may be the most difficult to plan and implement from a corporate business perspective. From a higher education view, Vaughn (2007) describes the characteristics of a blended online course as one that does not merely bolt on technology components such as an e-syllabus or announcement board, but is purposefully redesigned from the ground up, obtaining a gestalt effect that is uniquely different based on components that meld both face-to-face and online features. Vaughn (2007) suggest if these components are blended successfully, “the potential result is an educational environment highly conducive to student learning” (p. 82). These observations lend credence to the notion that the definition of blended learning is “fuzzy,” which from a research perspective would seem to indicate that we are at the early frontier of research in this domain of knowledge (Kim, et al., 2008; S.-W. Yoon & Lim, 2007). Other researchers are conducting observations and advancing various topologies or frameworks for measurement of blended solutions (Smith & Kurthen, 2007; Tang & Byrne, 2007; Verkroost, et al., 2008), which are leading to the development and refinement of conceptual theories to empirically advance the effective design of blended opportunities (S.-W. Yoon & Lim, 2007).

As theoretical research progresses, corporate and higher education advance with various deployment models at a rapid pace, with millions of learners already engaging in blended learning each day (Kim, et al., 2008; Vaughan, 2007). Benefits listed for blended learning sound vary familiar to those posited for distance education and e-learning (Appana, 2008), but espouse improvements over completely face-to-face or online only models such as: (a) lower student dropout rates; (b) higher student retention, satisfaction, and engagement; (c) improved cognitive student learning; (d) reduced operating costs through sharing resources, physical space and faculty teaching load; and (e) increased expansion of offerings to a broader audience (Tang & Byrne, 2007; Vaughan, 2007; S.-W. Yoon & Lim, 2007). Reasons cited to support these claims in higher education include: (a) increased learner control in pacing and sequencing based on their preferred learning style, (b) savings related to reduced student commuting cost, (c) increased variety of course selections permitted with flexibility of reduced on-campus visits, (d) elevated intimacy with course instructors and the online community, and (e) more engagement time with content (Berger, Eylon, & Bagno, 2008; Smith & Kurthen, 2007; Tang & Byrne, 2007; Vaughan, 2007). From a different perspective Kim et al. (2008) found some interesting patterns in corporate America that include feedback from the education, government, industrial, information technology, financial, non-profit, and medical business sectors.

Over ninety percent of those surveyed by Kim et al. (2008) indicate they were delivering blended learning already or were planning on doing so. The top benefits cited for blended learning include: (a) increased accessibility and availability, (b) improved learning experience, and (c) cost reductions (Kim, et al., 2008). When asked to rank the top-rated technologies planned for delivering blended learning, the following top three clusters appeared (Kim, et al., 2008): (a) web casting and video streaming, digital library content repositories, and knowledge management tools (tier I); (b) online simulations and podcasting (tier II); and (c) wireless and mobile handheld technologies and intelligent agents (tier III). Interestingly, while the rise of social networking was cited as a “trend” in prelim question one discussing online professional development in higher education, Kim et al. (2008) noted that wikis and blogs were rated very low in importance from a corporate perspective for learning, citing security concerns as a potential reason for their exclusion. The top tiered instructional methods reported for blended corporate learning fell into the following three tiers: (a) authentic cases, scenario learning, and self-paced learning (tier I); (b) problem-based and guided learning (tier II); and (c) coaching and mentoring, virtual team collaboration and problem solving, and simulations or gaming (tier III).

Kim et al. (2008) provide insight into several corporate blended models from International Business Machines (IBM), Cisco, and Shell that are worthy of brief explication. Shell and IBM utilize a field-based blended approach where Shell employees contribute content objects to an online repository based on authentic business problems for later knowledge sharing. IBM incorporates a four tier approach that begins by diagnosing learners' needs via online competency assessments, which then recommend reference materials such as web seminar archives, e-books, learning objects, and simulations. Human interaction occurs online at tier three via asynchronous discussions finally culminating with in-person classroom learning for role-playing, mentoring, and coaching to refine higher ordered skills at tier four (Kim, et al., 2008). Using a bookend blended approach; Cisco has employees begin online with course materials, coupled with feedback from a live instructor that also incorporates classroom experiences and online assessments (Kim, et al., 2008). Given this overview of blended learning benefits from both a higher education and corporate perspective, what examples are available in K-12 online professional development?

In a successful attempt to transform nine once-a-month school-based face-to-face workshops into a continuous nine-month blended professional development experience, Berger, Eylon and Bango (2008) drew from best practices in online moderation and developed a series of reflective low-threat online discussion tools that skillfully engaged 16 high school physics teachers in Israel with online discourse that was tightly coupled with the face-to-face pedagogical discussions. Berger et al. (2008) accomplished this through rich and immediate moderator responses, building off the teachers' online postings, face-to-face discussions, and facilitating teachers' analysis of student work online. Other studies also support the value of teachers listening to and reflecting upon student discourse as a way to improve their classroom practice (Hammer & Schifter, 2001). Teacher participation voluntarily continued four months after the completion of the experience, with researchers calling for further study on how to scale the model with less investment in moderators' time and using moderators different then those intimately familiar with the participants through the face-to-face PD component (Berger, et al., 2008). Less successful blended PD models at the K-12 level are also prominent, and may serve as exemplars of challenges to consider when implementing blended solutions.

Owston, Sinclair, and Wideman (2006) worked with 65 middle level science teachers as part of a larger blended solution that combined four face-to-face full day workshops interspersed between three 8-week online professional development experiences over the course of 25 weeks. During the course of this two year study that examined two separate deployments, Owston et al. (2006) shared that while the science teachers reported increased confidence in science content knowledge and transfer of inquiry-based pedagogical skills (which was confirmed through principal interviews, classroom observations and student surveys), the teacher participation levels in the online component was not as positive as they would have hoped. While an often cited challenge for teachers is that of insufficient time for professional development, this study provided funding and administrative approval for one half day a week release time for teachers to complete the online component. Ironically, researchers reported unforeseen problems that discouraged teachers from taking advantage of the weekly half day allowance, which involved: (a) challenges securing substitutes on a weekly basis, (b) allocating extra time needed to prepare substitute lessons, (c) difficulties gaining approval to complete work from home, (d) lack of space in school to sequester oneself to complete the work, (e) complaints from parents about amount of teacher absences, and (f) disapproval from other teachers not afforded the same PD opportunity (Owston, et al., 2006). The challenge of creating an online study environment at work is also found in the corporate workplace (Maor & Volet, 2007), and similar observations of low teacher participation in the online component of blended learning opportunities are found elsewhere (Yang & Liu, 2004). There may be confusion between the notion of increased learner-control and the necessary scaffolding and moderation needed for online learning to be successful. In a blended undergraduate study by Verkroost (2008), a completely open-ended learning environment was created to facilitate greater learner-control, which ultimately resulted in students expressing higher levels of frustration from insufficient online course structure and misappropriation of face-to-face meetings for transmission-based lectures versus group discourse and collaboration (Verkroost, et al., 2008).

A closer examination of the studies by Owston et al. (2006), and Yang and Liu (2004) reveal the importance of moderators in building a successful online community, and the criticality regarding the nature of the tasks assigned in an online environment (S. Barab, et al., 2001). Collaboration online should eschew individual single-posted monologues and center instead on facilitating pedagogical exchanges between participants that are closely tied to local curriculum and incorporate students' understandings and work samples as demonstrated in Berger et al. (2008) and Hammer and Schifter (2001). Possibly understanding the nature of the rate of PD implementation, monitoring tell tale signs such as: (a) late communication starts, and

(b) limited communication postings could have signaled mid course corrections to increase online engagement as recommended by Buzhardt, Greenwood, Abbott, and Tapia (2006). Maybe incorporating knowledge of the type of effective moderator feedback demonstrated by Lowes, Lin, and Wang (2007), such as “cheerleading + new information” might increase the sharing, reciprocity, and overall density of online communication (p. 194). Other researchers have also looked at the value of different tools instructors can use to increase learner motivation (Kupczynski, et al., 2008), and the value of immediacy and type of instructor feedback (Dennen, et al., 2007), which may be increase online participation, and minimize the “gatekeeper” role online facilitators sometimes need to play (S. A. Barab, Barnett, & Squire, 2002). Finally, understanding the work by del Valle and Duffy (2009) and Seok (2008) might provide insight into the various types of online learners, or the enumeration of skills, resources and theories for online success, respectively. Similar barriers to success exist in corporate and higher education as well. Participation in online virtual communities is also highlighted in both prelim question one dealing with online professional development, and question four regarding variables measured in online PD, with additional insight into teachers’ reasons for participating in these communities and challenges in their sustainability.

Kim et al. (2008) provide the following top five rated barriers for blended learning as enumerated from their international corporate survey: (a) fast-changing technology, (b) insufficient management support and commitment, (c) lack of understanding of what blended learning really is, (d) learners lacking self-regulated learning skills, and (e) organizational/cultural resistance. These very closely match those cited for higher education as well, where student challenges are cited as: (a) inadequate time management, (b) problems accepting responsibility, and (c) difficulties with using the technology (Vaughan, 2007). Faculty challenges for blended solutions in higher education in part include: (a) requests for additional design planning time, (b) assistance in creating constructivist-based activities that include rich interactive media, and (c) assistance in the administration and delivery of blended courses (Vaughan, 2007). The necessity of course design support is also documented in other reviews of online professional development (Aragon & Johnson, 2008; Maor & Volet, 2007). Vaughan (2007) concludes by listing administrator challenges in deploying blended learning solutions that include: (a) alignment and buy-in from an institutional perspective due in large part to cultural resistance to change, and (b) a lack of desire to collaborate across departments and colleges within the university. Interestingly, while similar barriers involving technology-enabled solutions to learning seem evident in all sectors (e.g., K-12, corporate, and higher education), this has little effect on other technology advancements, such as mobile phones, which march forward with tremendous adoption on a global scale (The New Media Consortium & EDUCAUSE Learning Initiative, 2009).

Before leaving the discussion on blended learning, there is another sub-theme that runs across both blended and purely online learning based experiences, that of student retention and attrition. Several recent studies looking at this issue reveal data showing that in completely online learning environments learner attrition may range between 50% and 75% for those systems that permit open enrollment (Jun, 2005; Kupczynski, et al., 2008; Liu, Gomez, Khan, & Cherng-Jyh, 2007), and in some extreme cases, may even reach 100% (Maor & Volet, 2007). Various theoretical models to help why explain student drop-out exist, which now include a focus on the part-time distance learner. The models identify the varied and intersecting environments where learning occurs (i.e., home, work, and the online study environment), and the psychological, social, physical, technological and temporal interplay that occurs within each learning environment (Cereijo, 2006; Fern University, 2003; Liu, et al., 2007; Maor & Volet, 2007). Major reasons for attrition in online learning include: (a) too little time to complete volume of work, or cognitive difficulty required for assignments; (b) lack of access and ability to use technology; (c) isolation and lack of interaction from other learners and course instructor; (d) lack of support, incentives, and buy-in from employer or administrator; (e) misperception of required workload and motivation to complete the work; (f) lack of content relevance to practical needs of work; (g) poorly trained course instructors unskilled in the nature of building rapport and community online; (h) poor course design and structure necessary to assist in self-regulating course completion; and (i) personal reasons beyond learners' control (e.g., career change, relocation, illness of self or family member, etc.) (Aragon & Johnson, 2008; Fern University, 2003; Jiang, et al., 2006; Jun, 2005; Maor & Volet, 2007). Many strategies have been suggested to increase retention that for the most part, includes addressing the areas listed above for attrition. Others suggest an on-boarding approach that include the following: (a) counsel learners before embarking in online learning, making them aware of the nature of the environment, workload, and time commitment; (b) conducting a technology readiness survey diagnosing learner preparedness and access to technology; (c) complete a required, but brief, online orientation course before registering for additional online courses; (d) incorporate multiple milestones within courses to support completion; and (e) provide additional support during the first few online forays to ensure success in the environment and continuity in continued course registration (Jiang, et al., 2006; Jun, 2005; Liu, et al., 2007; Maor & Volet, 2007). The Western Governors University (WGU) uses a competency-based model where students turn in individual projects to demonstrate growth as they complete online courses. A majority of WGU participants are classified as "performing" learners and need scaffolding to complete their courses, and as such, all learners initially begin in a highly structured, instructor-led environment upon entering the WGU (Jiang, et al., 2006, p. 357). Later, as learners mature in their ability to work online they are permitted to take on-demand web-based modules with only monthly instructor telecoms to monitor progress. WGU reports that collaborative projects are not conducive to their audience of adult professional workers, but facilitating voluntary support cohorts of students who are working on the same project is perceived as extremely valuable (Jiang, et al., 2006). This model appears important in online science education courses as well (Krall, et al., 2009), and is corroborated by other studies which document that not all learners equally value the need for learner-learner interaction (Rhode, 2009; Su, et al., 2005). In closing the discussion on student drop out rates from a blended delivery perspective, it would seem that the face-to-face component provides a measure of engagement, motivation, and accountability, that while desirable and achievable, for those that are too remote or lack the time to get to a physical campus, online courses are the only way they might gain access to learning (Cereijo, 2006; Hovermill & Crites, 2008). Perhaps, in a true blend of online learning, different opportunities may be presented as discussed in Rhode (2009), and Lapointe and Reisetter (2008) that allow learners to demonstrate their competency of learning outside of peer-interaction if desired. A discussion of the affordances of mobile technology will now be discussed.

Mobile Access, Probes, and GPS Technology Convergence

Mobile technologies were briefly addressed as a trend in prelim question one regarding professional development and will be expanded upon herein. Referred to as “m-learning,” mobile technologies sit at the nexus between e-learning and mobile computing, with the greatest advantage being that of immediate access to information and communication that is not constrained by proximity to a desktop computer, and true portability and “always on” access provide instantaneous consumption of varied media, as well as synchronous and asynchronous interaction, which in the purest sense of the word, provides anywhere, anytime learning (Caudill, 2007; Peters, 2007; Rekkedal & Dye, 2007). Some universities are making concerted strides to transfer many of the communicative exchanges and typical content available in online courses to also be available via mobile “smart phones” and portable digital assistants (PDA’s), evaluating their use for adult learners (Rekkedal & Dye, 2007). In seeking maximum flexibility and access to their online course content, the Norwegian Knowledge Institute (NKI) is conducting a two phase project that has ported a majority of the content from two online courses to be accessible via PDA and mobile phone technology (Rekkedal & Dye, 2007). Rekkedal and Dye (2007) report that adult learners agree that mobile connectivity effectively extends and increases access to course content and the communication between fellow learners and the instructor, but conclude it is an additive improvement, or an extension for learning, and would not supplant computer-based access. Adult users reported that tasks which involve content generation, such as writing assignments or consumption of interactive Flash-based media, may be difficult using mobile technology. This said, NKI provides an extensive list of future “just-in-time” learning support services they plan to make available via mobile technology such as: (a) password retrieval; (b) welcome messages, notifications, and reminders; (c) delivery of interactive quizzes; and (d) image, text and file uploads for profiles, blogs, and course assignments (Rekkedal & Dye, 2007). While formal communiqué features are worthwhile, others espouse the benefit of mobile technology to support the “connectedness” facilitated between online learners, or “teammates,” not necessarily for formal learning per se, but in maintaining a social awareness of colleagues via media and communication tools like Facebook, MySpace, Ning, Flickr, YouTube, and Yahoo Instant Messenger, etc. (McLoughlin & Lee, 2008a, 2008b; Tu, 2005). Readily facilitated through mobile technologies, these informal exchanges support building community, and ameliorate the transactional distance between learners when separated by time and place (Caudill, 2007; McInnerney & Roberts, 2004; Moore, 1993). Others suggest these technologies may also permit the co-creation and collaboration of knowledge (Cobcroft, et al., 2006; Tu, 2005). Mobile devices offer personalization, privacy, and access in workplace environments where network monitoring software and shared computer workstations often restrict access (Caudill, 2007). In a contemporary review of over 400 publications seeking a grounded view of global trends in mobile learning, Croboft, Towers, Smith, and Axel (2006) cite the following overarching benefits for m-learning: (a) supports a diverse range of learners from mature, to gifted, to remote, to those with special needs; (b) improves numeracy and literacy skills; (c) identifies learning and content needs through diagnostics; (d) engages, motivates, and focuses learners for extended periods of time; and (e) promotes self-esteem and self-confidence. In a review of current uses of mobile technology for learning in the medical field, Ducut and Fontelo (2009) provide a comprehensive recitation of applications that range across the following: (a) advance and post-session review of classroom lectures via podcasts; (b) formative assessment via polling and sharing class results; (c) real-time evaluations of students in the field and in the classroom; (d) mobile content libraries to assist clinical diagnosis of patients; (e) patient tracking, and accessing or updating records dynamically in real time; (f) telemedicine with the uploading of patient photos; and (g) social networking sites for doctors to exchanges ideas and opinions.

Without endorsing any particular platform, but by way of showing the immense potential for portable devices, the Apple iPhone with its downloadable app store now has over 35,000 applications available, with over 1 billion applications downloaded in its first 3 years of service (Apple Inc., 2009c). With its release of version 3.0 iPhone software, application developers may now create wired or wireless probes and external devices that communicate directly with the iPhone, which then provide real-time visual feedback to users via its embedded display (Apple Inc., 2009a). For example, one external device from Johnson and Johnson allows individuals with diabetes to monitor their glucose levels via tabular and graphical display, tracking their daily food intake and analyzing this against saved glucose levels over time (Apple Inc., 2009a). In the field of science education, much has been written about the value of digital probes and real-time graphical analysis that facilitate making conceptual relationships between variables in content areas such as electricity, motion, and sound (Lunetta, et al., 2007; Songer, 2007; Zucker, et al., 2008). With this latest interfacing software, there may be powerful implications for learning via the iPhone given its portability, Internet access, file upload capability, and built-in GPS mapping technology. Although, researchers caution implementing technology-enabled solutions too early in the learning process for younger students, which in certain cases, may inhibit deeper conceptual understanding (Lunetta, et al., 2007). Cautions noted, one can easily begin to imagine what is possible. Interactive on-location remote-sensing games, like "Environmental Detectives," developed by the Massachusetts Institute of Technology, allow college and high school students to use PDA's with GPS technology to traverse real-world locations as they assume the role of investigator taking measurements of ground water to uncover the source of a fictitious toxin, which threatens to shut down a controversial building construction project (The Education Arcade, 2009).

While mobile technology offers many advantages, disadvantages are also evident, such as: (a) access to the technology itself for teacher and student use; (b) limited screen size and text input as it stands by itself without peripherals; and (c) limited processing power and storage space to execute high volume and long term content creation, consumption and analysis (Caudill, 2007; Rekkedal & Dye, 2007). In a comparative research project commissioned by the Australian Flexible Learning Framework, Peters (2007) conducted a literature search and sought to triangulate the hype regarding m-learning against a purposive sampling of interviews from respected practitioners in both industry and education. While businesses were using mobile phones across a number of areas, of which formal learning was not cited as one, plans to increase capabilities were envisioned. From an education perspective, large potentials were listed, but at present, use was still experimental, with cost factors, teacher familiarity, and alignment within the curriculum cited as impediments to adoption (Peters, 2007). From an institutional support perspective, making a commitment to incorporate mobile computing is a major consideration and one not to be taken without proper planning given the decisions in content design (Rekkedal & Dye, 2007), and infrastructure decisions necessary for delivery that include: (a) transport options such as 3G , (b) coding development languages, (c) media options, (d) platforms such as HTML or WindowsMobile, and (e) delivery options such as email or SMS (Cobcroft, et al., 2006). On a tangential thread, McLoughlin and Lee (2008b) see the vast potential of social interaction and mobility, but caution instructors on issues regarding quality assurance of learner-generated content from a validity and reliability standpoint. Less circumspect, Tu (2005) views knowledge capture, acquisition and validation as supportive of constructivists pedagogies afforded with these new technologies. In summary, an armada of mobile Internet accessible devices are becoming available, blurring the line between laptops, tabletPC's, mobile "smart" phones, PDA's, netbooks, etc., which for learners, offer a wide variety of platform choices to address a wide range of functions for their individual learning needs (Ducut & Fontelo, 2009). Mobile smart phones such as the iPhone, which provide a user experience that can display and interact with many existing web content exchange options, such as: (a) YouTube and QuickTime video,

(b) HTML pages, (c) PDF documents, and (d) email and SMS instant messaging, would seem to offer increased flexibility and access at a relatively low price. With a review of the potential benefits and drawbacks of individual e-learning PD technologies discussed, a brief look at the tradeoffs across technologies will complete this discussion.

Summary of Tradeoffs

The individual benefits and detriments between the each of the following respective technologies has been discussed for the following areas: (a) remote access and manipulation via remote and virtual labs, simulations and hands-on learning; (b) learning objects and digital libraries; (c) online games and immersive multiplayer 3-D environments; (d) blended learning environments involving face-to-face and online experiences; and (e) mobile learning coupled with probes and GPS technologies. Looking across each area there appear to be trade-offs between the various technologies or delivery models in following areas: (a) mobility or portability; (b) accessibility; (c) usability; (d) start-up or production costs and time to market; (e) maintenance costs and resource overhead once produced; (f) degree of interactivity, fidelity and authenticity of content; (g) degree of learner-control; and (h) degree of social interaction. Comparing each of these technologies against each of these categories if discussed individually would require more text that permitted in this response, so Table 1 will be used to compare them succinctly across all these areas. Degrees within each category may range from high to low, and in certain cases, a descriptor of “depends” is used to convey the wide variability possible between the technology and the area under consideration. For example, simulations and games may be highly mobile if designed for target consumption on a phone, but have a very low mobility factor if designed for interaction from a desktop or videogame console. Similarly, the social interaction afforded for simulation and games varies again upon intended design, which may be low if only available as a single player game or high if it also supports multiple users with embedded communication features, such as is found in MMORPGs.

From a broad perspective, when looking across virtual and remote labs, learning objects, hands-on activities, simulations, or immersive environments, as one increases the fidelity, authenticity, degree of learner-control, accessibility, usability, degree of interactivity and social interaction provided, a corresponding increase occurs in production and maintenance costs, and time to market. Before ventures such as immersive 3-D multiplayer online role playing games, remote labs or extensive virtual labs are created, which in the case of MMORPGs can take years to develop and cost millions of dollars to complete, one needs to conduct a discriminative and meticulous market analysis that looks at the magnitude of the investment, the potential number users, and the shelf life for the product to determine if a viable cost recovery model is worthwhile. As previously discussed for education-based games and remote labs, this may require multi-institutional cooperation to make their use viable, and in the case of remote labs specifically, possibly forgo portions of the in-person equivalent. Hands-on experiences can be very scalable and sustainable in online learning if they leverage readily available items for simple inquiries, or very expensive, but still scalable, if necessary resources are allocated for the maintenance and distribution of kits. Unfortunately, the cost for incorporating kits may in large part be shifted to the learner, so if undertaken, should significantly increase the fidelity and authenticity of the inquiry learning experience. Start-up cost and resources to create and ship kits to individual students may require overcoming significant inertia, and as such, the hands-on non-kit approach seems more scalable, with a large upside for improving the online learning experience in science education. Additionally, shipping more complex technology such digital probes or measurement instruments may decrease the usability and classroom implementation factor for adult learners unless additional support materials, coaching, and demonstration media are generated to support their effective use (Penuel & Means, 2004). Careful thought should be taken in the analysis and design stage of course development if these more technologically complex solutions are included to facilitate learning. One of the potential advantages stated in the literature regarding learning objects is their reusability across multiple courses and potential to support large number of users, thus affording efficiencies in both scale and scope, but their potential has yet to be realized on a universal level. Perhaps utilizing Anderson's (2003) equivalency of interaction theorem could aid designers as they seek to balance the degree of interactivity afforded through various levels of engagement between student-student, student-instructor, or student-content against learning outcomes and cost benefits. Figure 1 displays the types of engagement possible and how learners may interact with the content, such as simulation-based learning objects, possibly through self study, which Anderson (2003) states "if well designed and applied appropriately [are] likely to enhance the learning experience" (p. 7). Anderson's (2003) theorem argues that as long as one of the three forms of interaction is strong (i.e., student-instructor, student-student, student-content), the other two levels may be provided at minimal levels, or possibly even eliminated altogether.

Blended learning solutions appear to offer the best of both face-to-face and online learning environments permitting high degrees of accountability, socialization, and online flexibility for learner control, which depending on the amount of media used in the online component, can be cheaper then some purely online solutions, with cost savings in physical space, faculty remuneration, and lower drop out rates. But these purported advantages merit further financial analysis, which the literature says is very difficult to execute on an institutional level. While some offer fairly comprehensive mathematical models that seek to capture all the cost associated with determining the return on investment of e-learning (Marengo & Marengo, 2005), others posit that the technology and methodologies are not mature enough to determine summative cost-effectiveness (Laurillard, 2007), and instead present far simpler selection methods that focus on the savings in time afforded as technology-enabled, constructivist-centric, and learner-centered methods are employed (Anderson, 2003; Laurillard, 2007; S.-W. Yoon & Lim, 2007). Regardless of the selection method applied, most agree that initial development and production costs of blended or e-learning solutions, which may incorporate learning objects, simulations, virtual labs, etc., are typically more expensive then traditional face-to-face transmission models and take a greater time to bring to market, given longer faculty planning time and the creation or aggregation of rich interactive media. (Appana, 2008; Laurillard, 2007; Morris, 2008; Vaughan, 2007).

Evaluative decisions regarding investment in online or blended course development usually include: (a) number of courses to be created, (b) production process to develop the course, (c) choice of instructional media to be included, (d) potential market for enrollments, (e) duration of the course, and (f) longevity or shelf life of the course (Laurillard, 2007; Lockee, Moore, & Burton, 2002; Markowitz, 1987; Twigg, 2003). Production and delivery costs, fixed and variable, may include the following: (a) media development costs; (b) repackaging costs of learning objects; (c) creation of remote labs; (d) content and lab access licensing rights; (e) faculty planning time; (f) consultancy fees; and (h) maintenance, operation and delivery costs that may include hosting fees, course management system and registration fees, promotion and marketing costs, help desk, library, and tutor support fees (d'Ham, et al., 2004; Laurillard, 2007; Lockee, et al., 2002; Markowitz, 1987; Scanlon, et al., 2004; Twigg, 2003). As is demonstrated by these lists, there are a myriad of expenses to capture in determining the costs of production and delivery for courses that have online components, and the tasks of tracking expenditures for district investments in K-12 professional development are not much easier (U.S. Department of Education, Institute of Education Sciences, & National Center for Education Evaluation and Regional Assistance, 2008). Researchers acknowledge the largely unfulfilled revenue promises of e-learning resulting from economies of scale, and recommend instead evaluating the benefits through economies of scope for online learning as resources, infrastructure, reusability of learning objects, and expertise are shared across and within institutions (Morris, 2008). Scanlon et al. (2004) typify this through their shared remote lab across four universities.

It would seem prudent to start small and conduct pilots with a limited number of instructors, providing the necessary redesign support to successfully leverage the advantages afforded through the blending of environment and media, while conducting iterative improvements over successive deployments as recommended by Dede (2009). From usability, accessibility, and learning potential points of view for science education, the value of blended solutions depends on the type of media or labs incorporated online and the type of interaction structured into the online and face-to-face components of the course. Theories and frameworks are surfacing to guide course developers and instructors in selecting among various strategies and technologies (Anderson, 2003).

Mobile learning and its affordances as related to probeware, GPS technologies, and access to social networking sites shows significant promise given their ubiquity and ability to extend more formal components of many learning environments. While at present most would agree mobile phones are not poised to supplant desktop and laptop computers as the primary platform for accessing e-learning content, they provide significant potential for increasing social awareness between learners, and for digesting or responding to brief snippets of content or services related to online learning. With respect to scalability, this in large part is already "at scale," but issues of sustainability from a financial point of view need to be analyzed depending on the type of services and content ported to mobile phones for online learning. Smart phones with Internet access and sufficient size screens may make this a viable proposition, as repurposing content for consumption via a mobile phone may not be necessary, and leveraging existing social networking and online applications are freely or cheaply available. One observation from the literature regarding the challenge for online adult learners to complete coursework is that of time, which at first glance, would seem to support the promotion of mobile learning, thus affording access whenever extra time is available (e.g., waiting in line at the grocery store checkout counter or while waiting for a doctor's appointment, etc.). While the literature promotes "always on" immediate access for the consumption of certain content like email, instant messaging, and small simulations or games, learners may still need longer periods of focused and uninterrupted time to learn more complex and conceptually deep constructs, so even with mobility, securing dedicated time to ponder, reflect, and digest content may still be a problem for adult learners juggling the complexity of a full time career, family and part time education.

In summary, the simplest answer regarding the selection of different technologies, media, instructional methods, delivery modes and locations for consumption is that "it depends". What this review has demonstrated is the potential benefits and limitations across these various technology realms for learning, which are rich and vast. What becomes obvious is that competent instructional designers are necessary to effectively leverage this wide array of opportunities to maximize the learning and motivation afforded in online learning environments.

Figure Captions

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

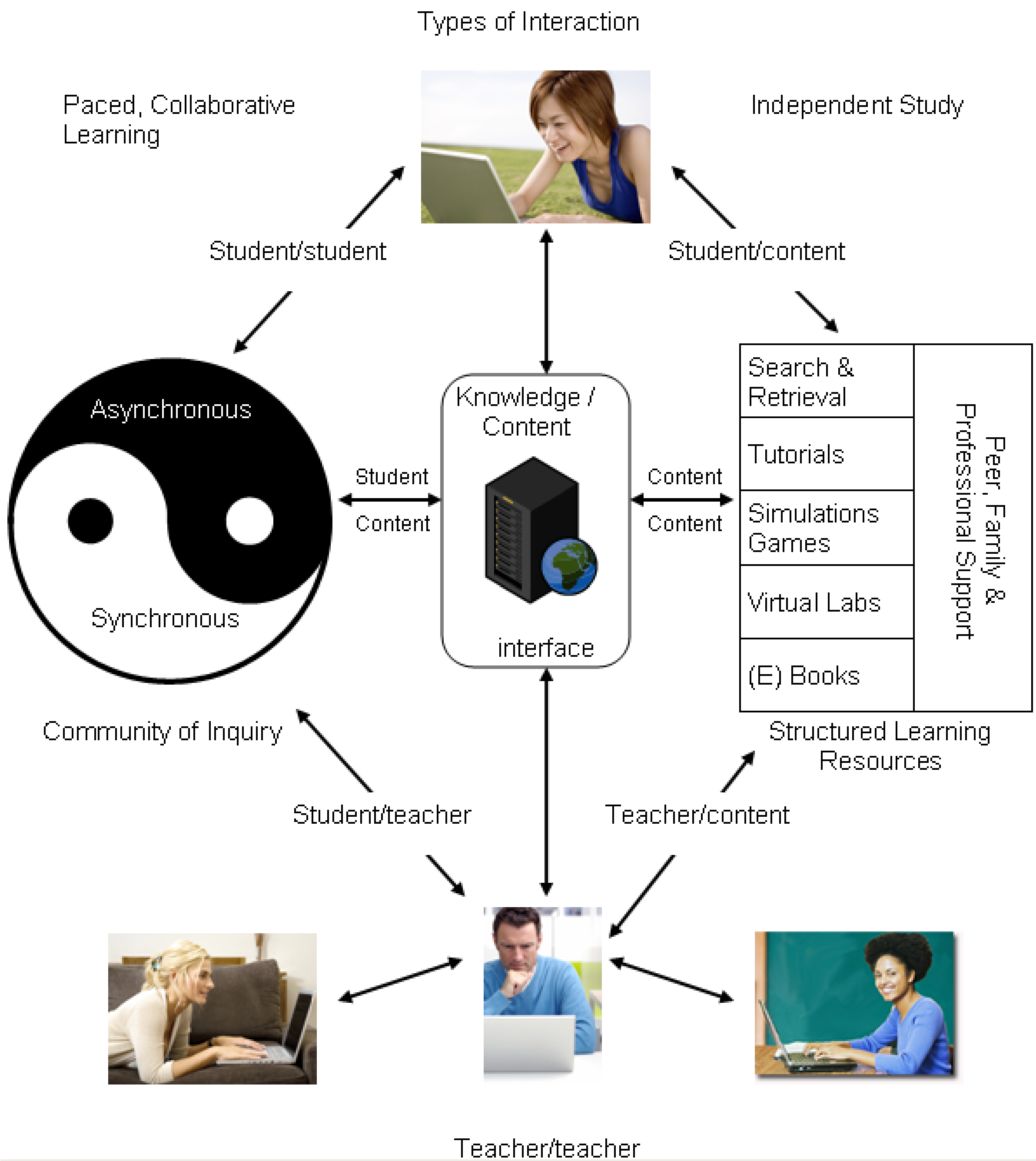

Figure 1. A Model of Online Learning

Table 1

Comparison of online learning technologies

	Attributes for Comparison							
Technology	Scalability	Mobility	Accessibility	Production Cost	Maintenance Cost/Overhead	Learner Control	Social Interaction	Content Interactivity
Simulations and Games	High	Depends	High	Moderate	Low	High	Depends	High
Remote and Virtual labs	Low to Moderate	Not Applicable	High	High	Moderate to High	Moderate to High	Depends	Moderate to High
Kit-based Hands-On	Depends	Low to Moderate	Moderate to High	High	High	High	Depends	High
Learning Objects	High	High	High	Moderate	Low to Moderate	High	Depends	High
Digital Libraries and Repositories	High	Not Applicable	High	High	Moderate	High	Depends	High
Massive Multiplayer Online Games	High	Depends	High	High	Moderate to High	Low to High	High	High
Blended Learning	Moderate to High	Depends	High	Moderate	Low to Moderate	High	High	Depends
Mobile and Social Networks	High	High	High	Low to High	Low to High	High	High	Low to High

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