Refereed Articles

Adult Science-Based Learning

The Intersection of Digital, Science, and Information Literacies

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Abstract: In today's learning environment, adult learners conduct learning episodes on the Internet meaning they are now expected to approach a self-directed science-based learning endeavor with knowledge of digital tools (digital literacy), knowledge of the science content (science literacy), and critical thinking skills to evaluate online resources (information literacy). Are adults equipped with such skills to discern credible science-based resources? If so, how are these adults discerning credibility, especially when they encounter conflicting science-based information. A recent qualitative study was conducted to delve into these questions. Participants engaged in real-time science-based Internet searches and provided feedback on rationales behind their credibility decisions. Findings from this study provided three strategies to assist those serving adult audiences in ways in which science-based resources might be best dissimilated online, especially when focused on controversial science issues such as fracking and climate change. The three strategies are (a) internally evaluate online resources, (b) conduct a usability study of online resources, and (c) stay dynamic with types of science-based resources and how to best meet the changing needs of the adult populace.

Keywords: adult learning, credibility, science literacy, digital literacy, information literacy

Introduction

> "... ADULTS INITIATING IN AN ONLINE SCIENCE-BASED LEARNING EPISODE MUST BE DIGITALLY LITERATE, SCIENTIFICALLY LITERATE, AND SKILLED IN DISCERNING CREDIBLE AND NONCREDIBLE INFORMATION ..."

The impacts of digital technologies on adult educative endeavors have been documented in literature for over 30 years. For instance, in 1982, Darkenwald and Merriam (1982) stated, "rapid technological and social change has direct consequences on the future of adult education" (p. 4). Digital learning technology continues to evolve thus impacting educative efforts in formal, informal, and nonformal contexts. How are these changes impacting adult learning? More specifically, how are these changes impacting the science-based learning endeavors adults conduct on the Internet? How are Internet science-based resources being evaluated by adult learners while online?

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Adult learners are utilizing technology in new ways, especially when it comes to learning. "New information and communication technologies exceed the traditional framework of the learning process" (Petnuchova, 2012, p. 614) thus requiring adults to approach learning differently than they might have in years past. In fact, research has shown "the key to improving the adult learning experience is to acknowledge diverse needs, expectations, and limitations in what adults want and need to know, and how they are prepared to experience it" (O'Toole & Essex, 2012, p. 183). Adults interested in learning on their own, referred to as self-directed learners, must possess skills necessary to conduct a learning endeavor. These skills include basic computer skills or digital literacy skills. These self-directed learners engaging with Internet-based science learning endeavors must possess a basic understanding of science processes, commonly referred to as science literacy skills.

Further still, these adults must possess a level of criticality in examining resources as many scientific topics popularized in the media have become politicized, polarized, and controversial. Self-directed adult learners must be able to distinguish credible and noncredible resources when learning on these controversial issues. Meaning that adults initiating in an online science-based learning episode must be digitally literate, scientifically literate, and skilled in discerning credible and noncredible information, or have a level of information literacy. This trifecta of literacy skills assists adults in discerning credible science information, thus empowering these adults to make more confident decisions on these topics when the need arises. Just as Hiemstra and Brockett (1994) advocated the need for empowering adults to take responsibility for their learning, this research study has shown that adults with tripartite literacy skills can locate and evaluate science-based information encountered while conducting a self-directed online learning endeavor.

Today's Adult Learner: Self-Directed and Connected

The concept of self-directed learning (SDL) has been around since the mid 1800s with the creation of lyceums and community groups (Brookfield, 1983). In fact, Brockett and Hiemstra (1991) encouraged educators to think of SDL as a lifelong learning approach as discussed years earlier by Knowles (1980). Knowles (1980) urged adults to be learners for their lifetime and not rely on the education from childhood to carry them through adulthood as knowledge becomes outdated over a span of one's life. Adults of today's digital society are learning outside of the traditional brick and mortar establishments. Technological devices serve as a main conduit for information.

Candy (2004) realized SDL often occurred when an adult was learning for fun which, he noted, should not undermine the worth of the learning experience. Candy (2004) stated that SDL "is often erroneously equated with the trivial, inconsequential or self-indulgent pursuit of hobbies or other specialized interests" (p. 3) yet "in its truest form, self-directed learning is a wellspring of individual expressions: It is the unfettered pursuit of interests dictated by one's personal values and aspirations" (p. 44). Candy's (2004) explanation of SDL is highly applicable to today's digitally connected adult learner. Given the popularity of Internet connectivity and availability of digital technologies, SDL endeavors take place spontaneously with great subject matter variability.

Shifting Learning Platforms for Self-Directed Learners

Tough (1979) stated that "changes in society will, in turn, result in people learning certain knowledge and skills that are not common at present" (p. 42). When he conducted his study over 40 years ago, adult learning episodes included films and television programs viewed in the privacy of one's home. These medias were thought to be "new ways of learning" (p. 120). While these are not new ways of learning by today's standards, there are new ways in which information is being delivered and new learning platforms engaging adults in SDL endeavors.

Research now indicates the Internet is replacing traditional sources of information (Takahashi & Tandoc, 2016), such as printed newspapers. "Our ability to keep pace with [technology] for learning is a measure of our ability to move with the times and to address adult learners' needs" (Irving & English, 2011). Learning on the Internet encourages more learners to engage with learning opportunities in a self-direct manner (Garrison, 2003). SDL's autonomous nature has been an

integral part in expanding the digital learning landscape. Digital learning options are a better fit to the learning qualities defined by SDL and the adult learner (Candy, 2004).

The Tripartite Literacies

In today's adult populace, adults are making many decisions with the Internet as their primary, and often, solo information source. Poynton (2005) stated the presence of digital tools is changing how adults do business and live their lives. His sentiments are still applicable today as adults need to possess skills allowing them to find and access resources, along with skills and knowledge that enable them to critically evaluate information when learning online (Garrison, 2003) as these critical evaluation skills can assist adults in finding credible resources (Wiley et al., 2009). In today's learning environment, it appears that adult learners are now expected to approach a self-directed science-based learning endeavor with knowledge of digital tools (digital literacy), knowledge of the science content (science literacy), and critical thinking skills to evaluate online resources (information literacy).

Digital Literacy

In observing today's learning society, digital tools and technologies offer highly interactive and personalized educative experiences for adult learners. Adults seem to be growing more engaged with digital tools and technology thus relying more on their digital literacy skills to find and access resources. This shift in learning platforms has caused self-directed learners to migrate from simply *learning* to becoming the *facilitator of their learning* (Irving & English, 2011). Adults with digital literacy skills are knowledgeable on the use of digital technologies and can locate, communicate, and share information through online environments, such as the Internet (Irving & English, 2011). Digital literacy skills allow savvy learners to extend the limits of still images and text-based learning through use of rich interactive resources (Fowler, 2001).

Science Literacy

As adults initiate science-based learning endeavors on digital devices, research indicates the need for these adults to possess a level of science literacy. For instance, Miller (2010) stated that "adults function as consumers, parents, patients, and citizens, and they will need increasingly higher levels of scientific understanding to make personal and political choices" (p. 191). This scientific understanding, or science literacy, is one's ability "to read about, comprehend, and express an opinion on scientific matters" (Miller, 1983, p. 30) or one's ability to understand the role of science and the scientific processes (Falk & Needham, 2013). Adults accessing online environments to learn more on science or scientific processes must already know something about their search topic as the adult learner is responsible for monitoring their learning and their comprehension (Song & Hill, 2007). Research has indicated problems arise when these adults do not have the understanding or expertise to facilitate their learning (Song & Hill, 2007). For instance, when those lacking science literacy skills are faced with conflicting information, they reportedly leave the science-based learning endeavor (Shen, 1975).

The dynamic nature of science can prove problematic to those lacking or deficient in science literacy skills as scientific facts and findings from today might be overturned by new research findings published tomorrow (Miller, 1998). For instance, in 1930, Pluto was named the ninth planet in our solar system. However, in 2006, scientists conducted further investigation into Pluto and the nearby celestial bodies in the Kuiper Belt determining Pluto lacked a "gravitational dominance" required to be classified as a planet (http://www.bbc.com/news/science-environment-33462184). This new discovery caused Pluto to be downgraded from a planet to a dwarf planet and the reclassification restructured classroom science textbooks. Children now learn about the eight planets in our solar system rather than nine planets. Science, by nature, is fluid. Research yields new findings and these discoveries can potentially impact what we had previously accepted as fact. Scientifically literate adults attribute these shifts to the nature of science and will most often critically examine research claims before blind acceptance.

Internet access opens the door to vast amounts of scientific information, yet "it has also removed or at least enabled a bypass of traditional filters and interpreters and exposed lay readers to both the full complexity of scientific discourse and a host of fraudulent claims" (Britt, Richter, & Rouet, 2014, p. 105).

This is a concern as website and resource evaluation has become the responsibility of the learner (Halverson, Siegel, & Freyermuth, 2010). Adults who access and engage with the Internet must be skilled to critically evaluate resources and make judgments on information quality. Adults lacking such critical literacy skills might not be as productive (Selber, 2004).

Information Literacy

The Internet is used regularly by adults wanting to make sense of new scientific processes (Takahashi & Tandoc, 2016) or search for science-based information (Segev & Baram-Tsabari, 2012). However, the Internet contains a wide range of scientific resources from credible to intentionally misleading (Britt et al., 2014). Research has identified the need for learners to possess critical evaluation skills to determine the quality of information (Candy, 2004; Irving & English, 2011; Karakas & Manisaligil, 2012; Song & Hill, 2007), the ability to discern between information and misinformation (Calvert, 2001; Karakas & Manisaligil, 2012; Metzger, 2007), and the awareness of online resources created to intentionally mislead learners (Jang & Kim, 2018; Piper, 2000). Research has reported roughly 75% of resources found online were considered unreferenced (Britt et al., 2014). "It is becoming increasingly important to understand what contributes to scientific learning, including information sources and trust in those sources" (Takahashi & Tandoc, 2016, p. 1).

Information literacy is important to adults who access and engage with SDL through online environments, as these adults must learn to make judgments on information quality (Song & Hill, 2007). Research indicated that "information literacy forms the basis for lifelong learning" (Association of Colleges & Research Libraries, 2000, p. 2) as information literacy "includes the ability to ethically and effectively find, access, evaluate, and use information" (Rapchak, Lewis, Motyka, & Balmert, 2015, p. 135). Information literacy skills allow learners to determine the type and quantity of resources needed while effectively and efficiently assessing the information they encounter in a critically manner (Association of Colleges & Research Libraries, 2000). So, one can state that adults assign credibility of online information, thus leading them to critically accept or deny assimilation of the information into their science-based learning endeavors.

The Literacies and Learning: From Then to Now

In 1961, Houle (1961) stated that "the next 20 years might see the development of new ways of learning new things" (p. 43). Almost 20 years later, Tough (1979) repeated Houle's sentiment and included a reference computers integration into learning as Tough predicted computers becoming more economical and user friendly which would in turn support learning and make resources readily available. Both sentiments have come to fruition. Currently, self-directed learners are conducting learning episodes on tablets, smart phones, and laptop sitting out on the beach or in a coffee shop. However, it seems little to no literature is available on how these learners are navigating these devices and the millions of resources to learn science.

Miller (1998) stated that it is important to have more research on resources used by adults in learning science. In today's digital age, adults engaging in online science-based SDL endeavors potentially have access to an unlimited virtual network of information and resources irrelevant of the topic of interest (Candy, 2004). While much research has been conducted on the espoused criteria used to evaluate credible online information, little to no research was found pertaining to real-time search data on credible science-based information.

The Study

In this study, eight participants were purposively sampled based on a set of criteria to participate in a two-part qualitative research session comprised of observation and interview methodologies. The study focused on collected real-time search data. All research sessions were conducted in the spring and summer of 2016 in a moderately sized coastal city in Georgia.

Participants

Participants were selected based on a set of six criteria to ensure adequate digital literacy competencies, subject matter interests, and availability to participate. Selection criteria for participants ensured participants (a) were of similar age, (b) were not considered science experts, (c) had interest in learning

more on controversial scientific topics presented through mainstream news, (d) knew how to conduct online information searches, (e) had transportation to the study location, and (f) had approximately 2 hr to volunteer for this research project. This criterion-based sampling approach as defined by LeCompte and Preissle (1993) aimed at recruiting a specific number of participants sharing common attributes.

Research Sessions

Eight research sessions, comprised of a computer search session and stimulated recall interview, were conducted. With each session, participants were asked to conduct two information searches, one on climate change and one on fracking. In total, the eight participants conducted 16 searches. Adapting Butefish's (1990) observation and stimulated recall interview to include more contemporary technologies in data generation and analysis afforded the best way to capture participants' thoughts as they reflected on their computer search. This methodology allowed participants the opportunity to talk through their decisions during the stimulated recall interview that occurred after the problems had been solved rather than during the problem-solving task.

The Focus

These three literacies described earlier were identified as an integral component for adults continuing their self-directed educative pursuits in today's unprecedented advances in the fields of science and technology and serve as the basis for the study conducted. The study's research sessions were implicitly designed to investigate the nonscience experts' skills in science literacy, digital literacy, and information literacy as they were asked to formulate thoughtful responses regarding a controversial science-based content area with which they had minimal to no prior knowledge. In identifying the arguments, participants were tasked to make judgments on the resources selected for incorporating into their research as they formulated a response regarding ways in which fracking and climate change cause concern for some adults in society.

The computer prompts asked the participants to go beyond rote search and find strategies to define terms as the participants were asked to identify and discuss possible controversies posed by the scientific process. Through this approach, the study captured real-time data pertaining to levels of digital literacy skills in locating information, science literacy skills in understanding the overall scientific process, and information literacy skills in critically reflecting on the credibility of the conflicting information they encountered on the Internet regarding these controversial scientific processes.

The Tripartite Literacy Conclusion

Participants showed digital literacy skills in locating science-based resources on the Internet. Hargittai and Shafer (2006) noted adults with digital literacy skills navigated and learned through the online environment effectively and efficiently. Participants from the current studied showed a level of digital literacy as discussed by Hargittai and Shafer (2006) as participants located information efficiently and effectively during each the research sessions. This current study's participant spent time with the resources they deemed credible and accessed while conducting their information searches. Data suggested all eight participants spent over half (58.9%) of their search times engaged with opened resources. Of the 16 searches (eight fracking searches and eight climate change searches), nine searches indicated participant engagement with resources over 80% of their search time. Meaning these participants were locating information and engaging with the resources for significant portions of their searches. From this behavior, the participants displayed functioning levels of digital literacies in that they were able to define new science-based terms and locate multiple resources pertaining to those terms.

Participants showed science literacy skills by providing accurate definitions and understanding of the science processes of fracking and climate change. Earlier research indicated online science-based information should be written to reach a wide range of reading skills and learning styles (Britt et al., 2014) as learning becomes problematic when learners do not understand the science content. Halverson et al. (2010) stated the lack of understanding of science content impacts how learners judge resources and how the learner incorporates the information into their learning. This is evidenced by the present study. Participants sought science content they could understand so the

content could be incorporated into their information search. When participants encountered conflicting information, they sought additional resources to help make meaning and resolve the conflict.

In making meaning of these topics and evaluating resources during the search process, participants noted credible science information was deemed "useful." Most participants indicated credible resources contained understandable language especially when presenting controversial or argumentative science-based information. Participants tended to navigate away from resources they perceived heavy in science jargon or containing elementary language. Participants wanted to be informed with age-appropriate facts of the controversy and be allowed to formulate their own interpretations. Participants did not want to be influenced by mere opinion or a one-sided presentation of information.

In comparing the fracking and climate change concerns identified by the eight participants, the participants located similar concerns for both controversial topics. Fracking concerns that were identified by the participants pertained to safety of the fluid insertion process, earthquakes resulting from fracking activity, water contamination underground and above ground, increased water consumption, and the ease in resource extraction through fracking negatively impacts dollars potentially used for exploration of more sustainable energy practices. Climate change concerns identified by the participants included the argument on whether it is a human-induced or natural-induced phenomenon, ocean temperature increases and is melting ice caps causing sea level rise, causing more severe weather, and causing potential animal extinctions. All participants arrived at a scientifically accurate definition of both controversial science-based terms and all participants provided accurate societal concerns.

Participants showed information literacy skills as they posited intelligible responses on why the processes might be controversial. Both science-based topics were outside of the participants' areas of expertise and the participants had varied backgrounds. However, participants began their search in a comparable way as they established a definition of each term. While not a resource of choice, their definitions of the controversial scientific terms are aligned to those definitions noted in *Merriam-Webster Dictionary*. The dictionary noted *fracking*, also correctly identified by the participants as *hydraulic fracturing*, as "the injection of fluid into shale beds at high pressure to free up petroleum resources" and *climate change* is defined as "changes in the Earth's weather patterns" (https://www.merriam-webster.com/dictionary).

With all participants seeking an initial definition, it can be assumed each participant was acknowledging a knowledge gap on the controversial topics. This behavior supports research identifying direct links between an adult's information-seeking behavior, their scientific knowledge, and their critical approach to evaluating the information (Takahashi & Tandoc, 2016) which are all aspects of information literacy. Participants relied on multiple sources to craft their responses to the computer search prompts asking why these concepts might be considered controversial. The average number of resources used was nine resources when conducting their responses to the fracking information and eight credible resources conducting their response for climate change information. As participants narrated their search, they indicated time spent checking multiple sources to validate credibility of earlier resources. Prior research indicated credibility evaluation is an iterative process (Warnick, 2004; Wathen & Burkell, 2002), and participants displayed such behavior in this current study as their definition and responses continued to build and change form with each synthesized resource.

In addition to identifying accurate definitions and concerns for both topics, participants identified one-side or "biased" resources. In discussing these controversial science-based topics, most participants indicated a need to locate as many facts as possible to ensure representation of "both sides" or all sides of the controversy. If both sides were not presented, participants indicated they did not find these resources credible due to the obvious bias. Behavior varied in how they responded to biased resources. For instance, some participants continued reading acknowledging they were interested in what "the industry" had to say about fracking. While others navigated away from the biased resource once a bias was realized. Irrelevant of staying on the resource or navigating off the resource, participants identified a bias of the resources that was taken into consideration during their learning endeavor.

In 2003, Garrison stated that adults need to possess skills to find and access resources, but also skills and knowledge that enable them to critically evaluate information when learning online. Participants in this study proved themselves competent in both locating credible science-based resources and critically evaluating online resources. Prior researchers identify these critical evaluation skills as essential for adults searching for credible resources (Wiley et al., 2009), and these characteristics were identified as main tenets of one who possesses information literacy skills (Association of Colleges & Research Libraries, 2000).

The Take Away

The findings from this study suggest, while a simple checklist of credibility might not be possible at this time in science fields, adults lacking subject matter expertise seem to have tripartite literacy skills assisting them in navigating the enormous quantity of online resources and evaluate the quality of these resources. Science has become increasingly lucrative, political, and social. Those responsible for disseminating such resources must take these factors into consideration. No longer can facilities or educators simply upload science-based resources and assume adults are locating those resources or assume the adults are perceiving those resources as credible. The learning transaction is growing more complex due to advancements in the science-based subject matter and technological interface and the varying needs of the adult learner. This transactional interface needs to be built on trusted sources, safe interfaces, and interested adults. Those uploading science-based resources, especially pertaining to controversial subject matter, can positively impact the learning transaction by learning how adults identify credible science-based resources.

The present study implied that adult learners expect science-based resources to be effectively and efficiently presented to them during an online learning episode and, while their expectations of online science-based resources are based on their experiences, presentation of science-based information seems to be driven in a consumer driven manner. For instance, adults want professional-looking web pages. Adults want to find items quickly. Adults want the facts, all the facts, not just the pleasant ones. Adults have limitations on what they are willing to consider. Adults value reputation. Adults want to be able to relate. Adults value what trusted others have to say. From the above list, it is hard to differentiate whether the adults are shopping for a great pair of marathon running shoes or whether the adults are interested in learning more on climate change. Adults, like the fields of science and technology, evolve. Adults have seemingly evolved in their needs, their thinking, and the ways in which they choose to learn. Therefore, one can say that science educators, science communicators, and adult educators should continue to stay dynamic in the ways in which they present science-based resources to this target audience. Online science-based resources must evolve too and keep pace with adult learners.

Implications from this study provide three strategies for those serving adult audiences in an online capacity, especially when focused on controversial science issues such as fracking and climate change. First, internally evaluate online resources. Findings from this study support prior web page design literature indicating four principal areas web users consider when making judgments on a web page: (a) the ease of navigating through resources, (b) the visual appeal, (c) the function of resources, and (d) the access to the web page and resources (Schmidt, Liu, & Sridharan, 2009). Following these four areas of web page design, those disseminating online science-based resources can perform an internal evaluation of the resources they have published for public viewing. By spending time on the outside looking in, one can identify areas of improvements. Through these internal critical evaluations of the resources made available online, sponsoring agencies might positively impact credibility perceptions of their resources.

Second, conduct a usability study of online resources. For instance, step back to evaluate how useful is the information to the target audience? Participants from this study suggested "credible science information" was synonymous with "useful science information." To have useful information provided to the adult learner, one might choose to identify how their science-based resources are being used by target adult audience. Oakley and Daudert (2016) claimed a website's usability study is "a cost-effective way to ensure users can fluidly accomplish intended tasks on a site" (p. 263). In a usability study, the selected participants navigate through a specific set of

science-based resources to accomplish a series of tasks. The participants feedback on the tasks provide insight into the website's usability. Should participants have difficulty accomplishing the tasks, then the resources might not be as useful as the agency assumed. Offering the opportunity for feedback on web-based resources can provide meaningful insight into how the target audiences are using, or not using, the science-based resources provided online in addition to insight into how the credibility of the science-based resources are being perceived.

Finally, those disseminating science-based resources need to stay dynamic in web-based resource offerings as science and the needs of the audience change. By maintaining a currency to digital, science, and information literacy skills, adults might continue to successfully navigate through credible science-based information. Bottom line, constructs used to distinguish credible science information are varied and complex. However, the current study supports the notions that tripartite literacy skills enable the nonscience expert participants to facilitate online learning, identify credible science-based resources, and synthesize new science-based information as they strive to make meaning of complex science-based topics.

Concluding Comments

Digital learning devices and social media are being used at historic highs to disseminate information as a recent Pew report indicated 62% of citizens in the United States retrieve their news through social media outlets (Jang & Kim, 2018). Science has become integral in many facets of society and our everyday lives. Science provides homeowners fertilizers and pesticides to help gardens grow. Science has afforded many ways in which we can power our homes and cars. Science provides health to communities through vaccinations, water treatment facilities, and sewage treatment facilities. Science feeds thousands around the world with genetically modified crops and hydroponics. Science allows us to travel around the globe and beyond. Science is amazing and amazingly complex.

However, adults are encountering situations in which they must make meaning and find logic in controversial, complicated, complex scientific processes, oftentimes without expert guidance. This conflicting science-based information can cause immediate or delayed dissonance. Online science-based resources can influence large-scale elections, types of vehicle to purchase, or fertilizer application details. Science information can be used to influence society. Science information can be used to scare society. Having skills to discern credible science-based information from noncredible science-based information can empower adults to save a life or save some money or save a planet. Digital literacy skills, science literacy skills, and information literacy skills are lifelong learning skills that equip adults to critically evaluate the credibility of the science-based resources they encounter.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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