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The Case for Digital Timelines in Teaching and Teacher Education

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Abstract: Digital timelines have been both transformational and supportive in enhancing the ways in which information is shared through text, images, interaction, and creativity to achieve course goals and objectives across numerous disciplines. In analyzing the experiences of teacher candidates (TCs) in their creation of a variety of resources to address the development of their digital competencies, it is worthwhile to further explore the design and effectiveness of one resource in particular, digital timelines. Thus, the aim of this paper is to explore TCs' development of digital timelines in a senior science methods course and to demonstrate the ways in which digital timelines can assist educators in their practice. Through surveys, interviews, and student coursework, the author examines TCs' attitudes towards technology, experiences with creating digital timelines, and their utilization of technology to promote and foster global skills and competencies. Findings of this study indicate beneficial effects of developing digital timelines including flexibility in achieving a variety of learning goals (including multi-scale analyses, visualizing different spatial and temporal arrangements, developing historical contexts, etc.) associated with the assignment, flexibility in application and actualization, and enhanced motivation and engagement. TCs engaged in knowledge construction as they created visually-enhancing and interactive timelines, and in doing so circumvented reducing, simplifying, and imposing linearity on complex scientific discoveries in the history of the discipline. TCs achieved success in developing scientific timelines that effectively immersed their peers in dynamic multimedia learning environments offering multiple sources of text, images, games, video, and audio, among other multimodal components.

Keywords: digital timelines; teacher candidate; teacher education; 21st century skills

Résumé: Les ligne du temps numériques ont été à la fois transformationnelles et favorables en améliorant la manière dont les informations sont partagées à travers le texte, les images, l'interaction et la créativité pour atteindre les objectifs du cours dans de nombreuses disciplines. En analysant les expériences des candidats enseignants (TC) dans leur création d'une variété de ressources pour aborder le développement de leurs compétences numériques, il vaut la peine d'explorer plus avant la conception et l'efficacité d'une ressource en particulier, les ligne du temps numériques. Ainsi, l'objectif de cet article est d'explorer le développement par les CT de ligne du temps numériques dans un cours de méthodes scientifiques de haut niveau et de démontrer les façons dont les ligne du temps numériques peuvent aider les éducateurs dans leur pratique. Au moyen d'enquêtes, d'entretiens et de cours d'étudiants, l'auteur examine l'attitude des TC à l'égard de la technologie, les expériences de création de ligne du temps numériques et leur utilisation de la technologie pour promouvoir et favoriser les compétences et compétences mondiales. Les résultats de cette étude indiquent les effets bénéfiques de l'élaboration de ligne du temps numériques, y compris la flexibilité pour atteindre une variété d'objectifs d'apprentissage (y compris des analyses multi-échelles, la visualisation de différents arrangements spatiaux et temporels, le développement de contextes historiques, etc.) associés à la mission, la flexibilité dans l'application et actualisation, et une motivation et un engagement accrus. Les CT se sont engagés dans la construction des connaissances en créant des ligne du temps interactifs et améliorant visuellement et, ce faisant, ont contourné la réduction, la simplification et l'imposition de linéarité sur des découvertes scientifiques complexes dans l'histoire de la discipline. Les CT ont réussi à développer des ligne du temps scientifiques qui immergeaient efficacement leurs pairs dans des environnements d'apprentissage multimédias dynamiques offrant de multiples sources de texte, d'images, de jeux, de vidéo et d'audio, entre autres composants multimodaux.

Mots-clés: chronologies numériques; candidat enseignant; formation des enseignants; compétences du 21e siècle

Introduction

With each passing year, digital technology becomes a more predominant part of educational culture (Bolstad et al., 2012; Cox, 2008; Varier et al., 2017). The mere introduction of technological tools and digital infrastructures has not triggered beneficial or meaningful educational change; rather, changes in systems require teachers who understand the complex interactions of teaching, learning, and technological affordances as determined by and situated in context (e.g., Mishra & Koehler, 2006; Rosenberg & Koehler, 2015). Moreover, technology cannot be effective in the classroom without teachers who are knowledgeable about both the technology itself and its implementation to meet educational goals; that is, teachers who are technologically literate. Thus, it can be said that, while technology use in the classroom is increasing (Higgins et al., 2012; Bang & Luft, 2013), improving learning through the application of these literacies should remain the goal. Changes are needed if technology is to make a difference in curriculum design and address the needs of all learners (DeCoito, 2017). Technology can be a tool for worthwhile educational experiences, but we need to ensure its use fulfills specific educational goals.

The impact of technology and the changing face of curriculum, as well as the accompanying changes in the roles of teachers, can no longer be ignored; roles must be reconceived in order to engage learners in many decisions about their learning. Achieving changes associated with the integration of technology in the overall learning environment requires efficient teacher training in teacher education programs (Bullock, 2016; Davies & Merchant, 2014). Teacher education programs have sought to prepare teacher candidates (TCs) to be proficient in their designated academic disciplines, as well as highly adept and resourceful across numerous other aspects of teaching. In the process of achieving these goals, particular areas—such as digital competence and digital literacy—have seen a blend of traditional methods, and newer alternatives merge to foster the growth of corresponding skills and attitudes (see, for example, projects such as web-based inquiry science environment (WISE) [Linn et al., 2004; Slotta & Linn, 2009] and learning technologies in urban schools (LeTUS) [Hug et al., 2005]). Despite the aforementioned progress, on-going inquiry-based approaches imply that support should go beyond teaching skills in technology use and focus on the effective pedagogical use of the technology to support teaching and learning goals (DeCoito & Richardson, 2016). Timelines, for example, highlight how a traditional learning concept and resource (i.e., creating timelines to share and represent data), can be enhanced through the integration of digital technology to unpack new teaching and learning possibilities, many of which can be positive and beneficial for educational stakeholders (Twyman et al., 2006).

Research Questions

This paper is derived from a larger mixed-methods study of the development of science TCs' digital competencies as they explored the integration of digital literacies in a science methods course. In this paper, the author reports on one course assignment, the development of digital timelines, and explores the following questions: (a) Do TCs' experiences with creating digital timelines inform how they perceive digital technological tools and resources to assist them in their practice? (b) What are TCs' understanding of the affordances and constraints of the digital technology for supporting knowledge construction? and (c) How can digital timelines act as multimodal tools to help convey information to a wider audience?

Literature Review

Constructivism and Technological, Pedagogical, and Content Knowledge (TPACK)

The preparation of young people for lifelong learning in a knowledge-based, information society has become an increasingly important objective of educational systems worldwide (Dagienė, 2011; Plomp, 2013; Schellinger et al., 2019). A primary challenge for educators is the transformation of students' learning processes in and out of school to engage student interest in gaining 21st century skills. Lemke (2004) reported a link between 21st century skills and academic achievement, making the case for incorporating teaching activities that help students develop 21st century skills (see further elaborations, National Research Council, 2011; Ontario Ministry of Education, 2016). Despite the fact that educational systems have long identified 21st century skills as key learning outcomes, currently the challenge is—according to Lemieux and Roswell (2020) and Zhao, Wehmeyer, Basham and Hansen (2019)—how to achieve a shift that creates a more coherent educational ecology that can support what is known about good learning and that can accommodate new knowledge about learning and, importantly, new purposes for learning in a changing world.

The acquisition of 21st century skills in teaching and learning will require a shift in what we teach, how we teach it, the tools we use, and how we educate, train, nurture, and retain our teachers. It is undeniable that we cannot change how our students learn unless our teachers are equipped to teach in new ways (Bang & Luft, 2013). Thus, the scope and components of this study were informed by the conceptual framework of a constructivist model of learning applied to teacher education—acknowledging that for TCs to develop their ability to teach, they must be provided opportunities to actively construct their understandings of pedagogical content knowledge (Shulman, 1986) and technology (Mishra & Koehler, 2006), and integrate new understandings with prior knowledge (Hollingsworth, 1989). This will require that TCs possess technological literacy, which is defined as the ability to effectively use technology to access, evaluate, integrate, create, and communicate information to enhance the learning process through problem-solving and critical thinking (Sedivy-Benton & Leland, 2014) encompassing three interdependent dimensions—knowledge, ways of thinking and acting, and capabilities (Pearson & Young, 2002).

The technological, pedagogical, and content knowledge (TPACK) framework is used by researchers to better understand how teachers support student learning through technology integration in their practice (Voogt et al., 2013). The three major constructs combined in this framework are: the technological knowledge (TK), which refers to knowledge about technologies for use in teaching and learning; the pedagogical knowledge (PK), which refers to the processes and methods of teaching and learning; and the content knowledge (CK), which refers to the subject area understandings (Pringle et al., 2015). Although Baturay et al. (2017) found TK to be the biggest indicator of technology inclusion in practice, it is the complex interactions among these three elements in specific contexts that define teachers' ability to teach effectively (Koehler & Mishra, 2009). Combining these constructs, both theoretically and practically, would produce the knowledge needed to successfully integrate technology into teaching. The importance of understanding TCs' prior beliefs, attending to subject-specific pedagogy, the importance of the academic task as part of the teaching knowledge base, and TCs understanding of the affordances and constraints of digital technology for supporting knowledge construction are highlighted in this study.

The Role of Digital Technology in Education

Education today is faced with the challenge of adapting to an environment where literacies are becoming ever more important—how knowledge is represented, as well as the mode and media chosen, is a crucial aspect of knowledge construction, making the form of representation integral to meaning and learning more generally (Martin & Grudziecki, 2006). It follows, then, that to better understand learning and teaching in the multimodal environment of the contemporary classroom, it is essential to explore the ways in which representations in all modes feature in the classroom (Jewitt, 2008).

The importance of digital technological tools and resources can be informed through 21st century skills and global competencies frameworks (Organization for Economic Cooperation and Development [OECD], 2018). While educators and others have listed and described 21st century skills, teachers continue to search for strategies to effectively address the development of these skills in the preferred learning styles of today's students (Zhang & Martinovic, 2008). Despite technology being inherently interesting, the focus should be on how it is used and the content it conveys; it has to aid in presenting problems as both challenging and solvable in order to engage students (Willingham, 2010). It should be noted that although students can do many things using digital tools in service of their out-of-school social and entertainment interests, when it comes to learning they need supports, modelling, and opportunities to practice a range of skills (Pangrazio, 2018).

In science education, Windschitl and Sahl (2002) found that technology could facilitate teachers' use of collaborative and project-based pedagogies, which was dependent on the teachers' beliefs about learners, their understanding of the roles of technology, and their knowledge about how technology could enhance science teaching. Sorensen et al. (2007) found that science teachers who learned about technology in their teacher preparation program were prepared to use technology in more substantive and meaningful ways. These studies and others suggest that teachers can learn to use technology effectively, and teacher preparation programs can play important roles in the way technology is implemented in instruction (Bang & Luft, 2013). Moreover, Dede (2014) maintains that the goal of using technology should be to empower teachers to make better use of instructional strategies that provide opportunities for self-directed learning to foster academic engagement, self-efficacy, and tenacity by requiring students to define and pursue specific interests. Furthermore, the use of technology should personalize learning, which ensures that students receive instruction and supports that are tailored to their needs and responsive to their interests. One such instructional strategy, digital timelines necessitate the development of global competencies, address technological skill development, and can be utilized effectively as a pedagogical resource by teachers and educators.

Visual Resources and Multiple Representations

Multiple representations are examined using the Integrated Model of Text and Picture Comprehension (ITPC) (Schnotz, 2014; Zhao, Schnotz, Wagner, & Gaschler, 2019). Through this model, a set of guidelines are illustrated to facilitate an instructional design and to address many forms of multiple representations. These guidelines suggest that a design should incorporate elements that cater to principles such as text-picture coherence—different types of text modality to fit different selections of pictures and images (static, animated, etc.)—and spatial and sequential considerations, resulting in an end-product that is learner-oriented and focused on the necessary and relevant elements of multiple representations (Schnotz, 2014). In realizing this, it becomes clear that digital timelines can be best produced, and subsequently interpreted and understood by the creators and target audiences, by ensuring that effective uses of the various forms of multiple representations are congruent with selected multimodal elements. In this paper, digital timelines developed by TCs are not intended to represent all of the history of science but to give an overview of important events in an accessible and engaging manner. The purpose of the digital timeline project is not to discover new knowledge in the field of the history of science but to communicate insights from the field.

The ITPC model aligns with human cognitive architecture in learning and helps educators understand the need for using certain multimedia principles when designing instructional presentations and/or lessons that use multimedia formats. Educators who take into mind the dual processing channels (auditory-verbal and visual-pictorial) of students can help students with modalities suited to the students' learning styles. In addition, this leads to better comprehension, more transference from sensory registers to working memory, and finally long-term memory (Schnotz, 2014).

The importance of visual representations is paramount in understanding the effectiveness of digital timelines as visual, educational resources that offer different avenues into information representation and interpretation (Spires et al., 2012). Opfermann et al. (2017) discuss the value of multiple representations in physics education:

> Many concepts, processes or relations can be comprehended much more quickly when some kind of picture is provided because pictures are able to show at once what would take much longer to be described with words or demonstration experiments. Furthermore, students are able to visualize the rather abstract contents of physics topics being taught such as with the block and tackle. Moreover, when using multiple sources of information, learners are able to choose those sources with which they prefer to learn, in this case the real tackle or the pictures. (p. 1)

In this study, digital timelines offer multiple sources of text, images, and audio, among other multimodal components. Thus, the hypothesis that these timelines offer multiple representations that are able to meet specific learner preferences and learner goals is warranted.

Digital Timelines: Tools, Resources, and Means of Engagement

Timelines have been used to explore the historical development of a number of disciplines (Kräutli, 2016; O'Neill, 2015; Thiry et al., 2013), and they offer numerous capabilities including situating events in context; placing new developments; categorizing events and relationships; explaining processes and procedures in a visual way; and showing development and exhibiting growth (Evans & Bradley, 2019).

In science education, researchers have found that students too often encounter bits and pieces of science out of context and unconnected to larger scientific themes. As a result, students fail to develop a sense of scientific era and do not connect individual events to larger movements and themes (Galili, 2018). For example, a vast majority of science textbooks and websites focusing on science content commonly include features highlighting major discoveries and their discoverers; however, these are typically brief and decontextualized. This situates discoveries in the framework of pedagogy-based or curriculum-based conceptual development, not chronological/historical development. As a result, students (and teachers) may forfeit the opportunity to experience the context-rich historical narrative of scientific discovery and invention. Furthermore, the expository representations of science in common teaching-learning materials may not provide a realistic depiction of the historical development of science, which occurred over a long period of time, led by scientists who were influenced by the people, politics, and cultures of their day (DeCoito, 2014). Digital timelines can help students understand the chronology of events and situate newly encountered events and figures in relation to those previously studied (Twyman et al., 2006). The process of multimedia learning can be viewed as knowledge construction, in which multimedia messages are aids to sense making (Schnotz, 2014).

The utility of digital timelines is an often-discussed topic among historians, mostly due to the question that arises over what sorts of implications they bring to History as a discipline. Generally, historians recognize and advocate for opportunities that utilize digital technology to shift the landscape in terms of how timelines are presented (O'Neill, 2015). This is one example of enhanced interest and a positive attitude toward the role of digital technology in maintaining public records ahead of long-standing uses of traditional, text-based timelines.

Student engagement is also cited as a benefit of digital timelines. When digital timelines were demonstrated in a social studies class at the elementary level, students were found to be highly engaged with many students attributing the wide use of several multimodal components as a catalyst for their increased interest in the timelines (Wilson et al., 2007). It is important to consider that while the elementary students were interacting with digital timelines (as a collection of multimodal resources) for the first time in their classroom, it may have also been their first time encountering the effective use of multiple representations coalescing to impact their learning.

Notably, a common issue that students encounter with creating traditional timelines is their tendency to solely represent history and important events in a linear fashion (Picard & Bruff, 2016). This suggests that, more often than not, students are neglecting to capture the contextual relationships and other potential meanings from their work beyond simply connecting the events. By choosing to create timelines digitally, students can rectify these shortcomings in their work; as they are able to include text, images, and other forms of multimedia to simultaneously connect individuals, places, and events together, thus creating a more informative and holistic timeline. These features are an integral part of the digital timeline assignment and the basis for this paper.

Methodology

Research Design

The study follows a mixed-methods design (Mills et al., 2010) to help meet the overall aim of the project and answer specific research questions. The study utilized data and methodological triangulation to strengthen the exploration of the development of TCs' digital competencies in a science methods course. The use of multimethod in a single investigation allows for the potential consideration of competing causal factors (Schutz et al., 2004). This permits for both qualitative and quantitative data types to provide insights into the phenomenon under study. These insights can complement one another or reveal divergences needing further exploration. For example, in the current study TCs' general views and perspectives about digital technology were obtained through the use of surveys. At the same time, TCs' interviews and coursework provided a better understanding of participants' responses on the survey items about the use of digital technology in developing technological literacy.

Coursework: Digital Timelines in Science

The implementation of technology was promoted widely in the science methods course to expose TCs to multi-literacy pedagogy and develop their technological literacy, as well as to engage them in creating digital science content and promote creativity. The expository representations of science in teaching-learning materials, and the shift in the new media age had a catalytic effect in terms of including the digital timeline assignment as part of TCs' coursework. The assignment was designed using the ITPC model (Schnotz, 2014) focusing on elements that cater to principles such as text-picture coherence—different types of text modality fit different selections of pictures and images (static, animated, etc.)—and spatial and sequential considerations. The resulting end-product is learner-oriented and focused on the necessary and relevant elements of multiple representations.

The assignment required TCs to develop digital timelines in science using a variety of software (e.g., Prezi, Timetoast, Movie Maker, Tiki-Toki, etc.) and incorporating simulations, digital games, virtual laboratories, videos, interviews, to name a few. The goal of the assignment required TCs to prepare a digital-based presentation suitable for inclusion in a continuous scientific timeline based on significant discoveries and inventions that occurred within an assigned period of time in the history of science (DeCoito, 2014, 2020). The discoveries and scientists were embedded in specific scientific and cultural contexts that were designed to highlight the impact of the culture of the time on scientific knowledge. The rationale was to highlight the interconnectedness of the sociocultural milieu and the scientific dimension; thus, TCs were instructed to organize the timeline to reflect the flow of time but avoiding a linear progression which would indicate that these dimensions were not interconnected.

Participants

Participants included 16 TCs (13 females, 3 males) ranging in ages from 20 to 23 and enrolled in a senior science methods course in a Faculty of Education at a Canadian university. Seven TCs volunteered to be interviewed at the end of the study. Survey findings at the beginning of the course indicated that the TCs had some knowledge of technology-enhanced pedagogy but lacked proficiency in terms of developing and applying pedagogical strategies using digital technologies.

The author was the researcher and the instructor for the science methods course. In an effort to practice reflexivity as a researcher (Creswell, 2007), the author recognizes her experiences and how they shaped the study's design and execution. In her practice, she promotes technology-enhanced pedagogy and adopts a research-based approach to teaching and learning with technology (DeCoito, 2020; DeCoito & Briona, in press; DeCoito & Richardson, 2016, 2017, 2018). In the case of digital timelines, the goal of this approach is to enhance TCs' technological literacy as they develop a better understanding of the nature of science, and to become more engaged in their own learning. In order to remove undue influence and to ensure that TCs' participation was truly voluntary, and that adequate procedures for mitigating the dual-role relationship were implemented, a research assistant coordinated the study. The assistant was responsible for: (a) introducing the study to the TCs; (b) recruiting and obtaining informed consent from TCs; and (c) conducting data collection (e.g., surveys, interviews, etc.). The instructor/researcher had access to the consent forms collected by the research assistant at the end of the course after all grades were finalized.

Data Sources

Data sources for the study included a 5-point Likert scale survey (strongly disagree [1] to strongly agree [5]) exploring TCs' views of, experiences with, and attitudes towards technology, and the development of digital timelines; TCs' reflections on the digital timeline; and student coursework. While TCs engaged in discussions on numerous themes and topics pertaining to their coursework in their interviews, only portions of the interviews pertaining to their experiences with creating digital timelines were analyzed in this paper.

Data Analysis

Quantitative data derived from the 5-point Likert scale survey exploring TCs' experiences with technology were inputted into Microsoft Excel and analyzed statistically. All TCs participated in completing the surveys. The results were tabulated, and the mean was calculated and graphically represented. Qualitative data (reflections and interviews) were analyzed through an interpretational analysis framework executed through the process of thematic coding and constant comparative method (Creswell, 2007) to help understand, for example, TCs' engagement with digital technologies during the course. The author and research assistant engaged in several steps in qualitative data analysis, including sorting and organizing raw data from the various categories into text for analysis. Next, the author and research assistant individually read through the text multiple times to capture content and meaning of TCs' understanding, experiences, and perception towards digital technology and to identify themes across their responses. The digital timelines were analyzed for text-picture coherence (Schnotz, 2014), and spatial and sequential considerations. Specifically, the analysis focused on (a) the content of the timelines, including the nature of information and its organization; (b) how the content was communicated, including text, graphics, videos, etc.; and (c) creativity and originality.

Findings

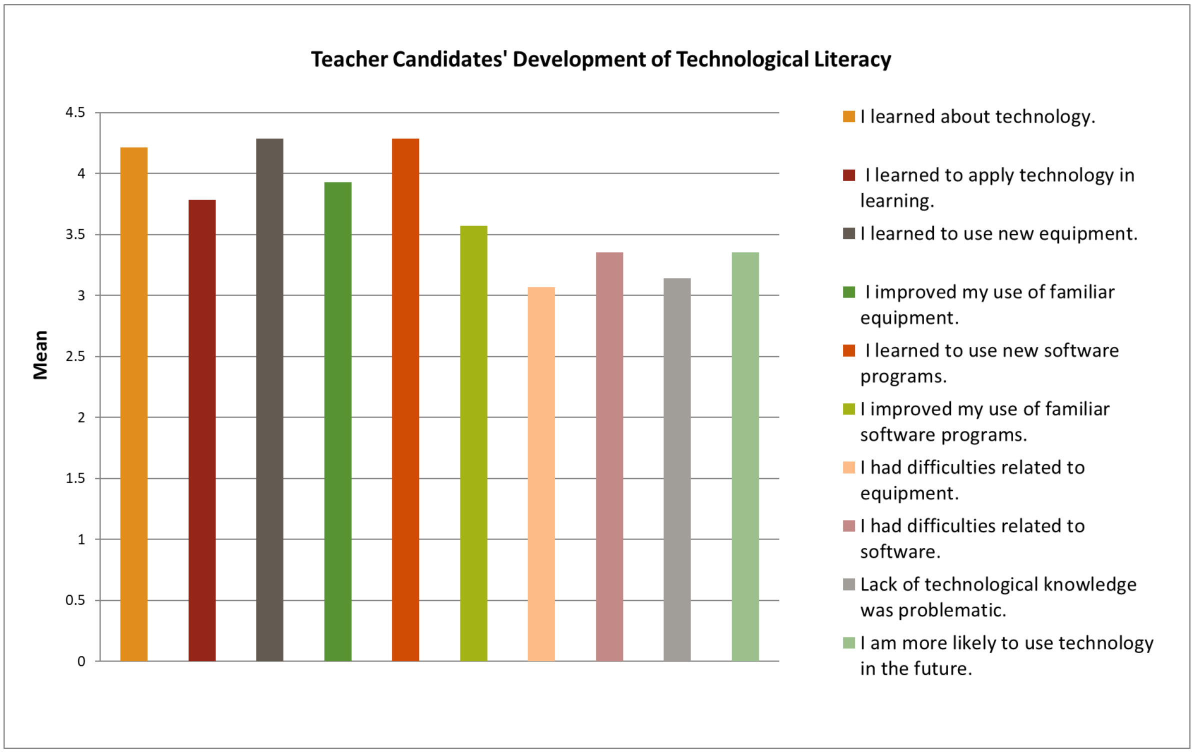
Findings indicate that TCs created visually-enhancing and interactive timelines and, in doing so, circumvented reducing, simplifying, and imposing linearity on complex scientific discoveries in the history of the discipline. TCs achieved success in developing scientific timelines that effectively immersed their peers in dynamic multimedia learning environments offering multiple sources of text, images, games, video, and audio, among other multimodal components.

Developing TCs' Technological Literacy

Survey findings reveal that all TCs agreed that they enhanced their technological literacy by learning about technology, unfamiliar equipment, and software programs through the development of digital timelines. The vast majority of TCs felt that they had acquired the necessary general technological skills for creating their digital timelines, with a few TCs reporting significant difficulties using the necessary computer equipment or software. As well, the lack of technological knowledge was challenging for some TCs (Figure 1).

Figure 1

Teacher Candidates' Responses to Survey Statements Exploring Technological Literacy



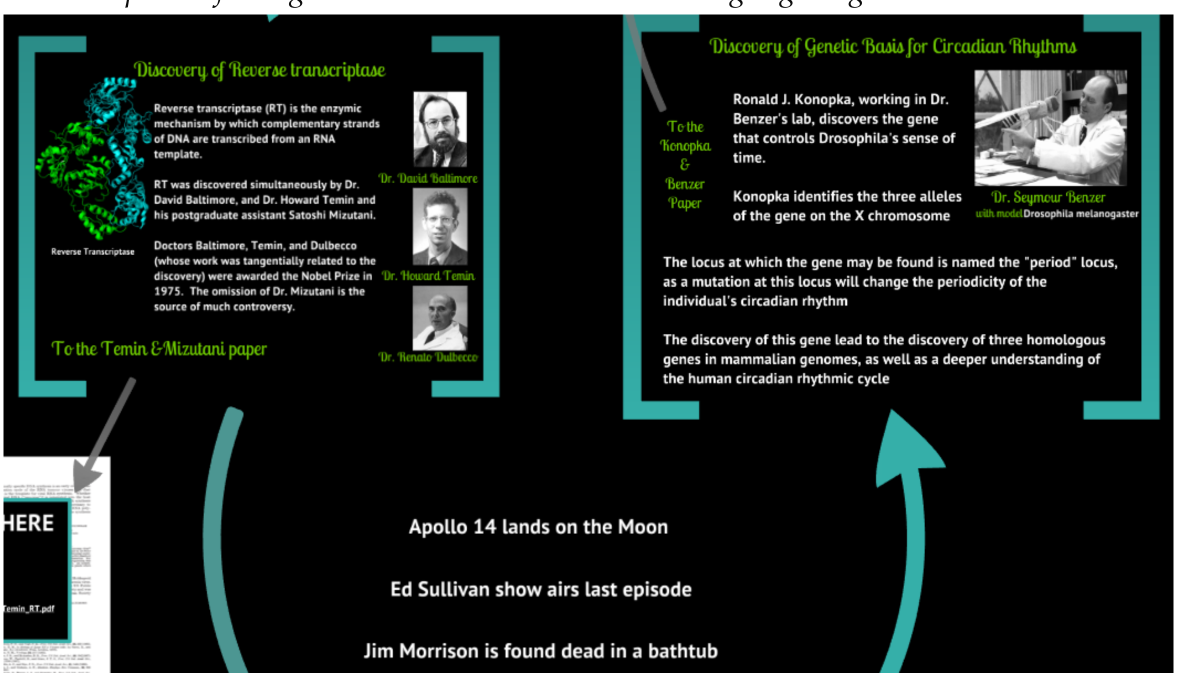
In the interviews, most TCs mentioned that they experienced “the usual” challenges associated with familiarizing oneself with a new computer application, but that “once familiarized with the program, it became much easier.” TCs were appreciative that the class was introduced to the software and provided in-class opportunities to collaborate on use of the software and discuss the content of their timelines. While TCs collectively displayed agreement in certain survey responses, not all TCs agreed that the newfound learning affected their intentions to incorporate technology in their future practice (Figure 1).

Knowledge Construction and Understanding Through Digital Timelines

Several TCs believed they were successful in constructing knowledge and conveying understanding through their digital timelines. One TC explained that for every scientific discovery included in their digital timeline, they were able to present a corresponding image and supplemental evidence of social context to solidify and reinforce the meaning of the scientific discovery. This enabled not just more clarity and an uncomplicated understanding of science concepts, but it demonstrated how different disciplines overlap each other in that process. Figure 2 highlights a segment of a digital timeline, created in Prezi, demonstrating social context in science. Between the discoveries of reverse transcriptase in 1970 (left) and the genetic basis for circadian rhythms in 1971 (right), there are also significant events occurring in astronomy, entertainment, global issues, and the economy simultaneously.

Figure 2

A Screen Capture of a Digital Timeline Created in Prezi Highlighting Social Context in Science



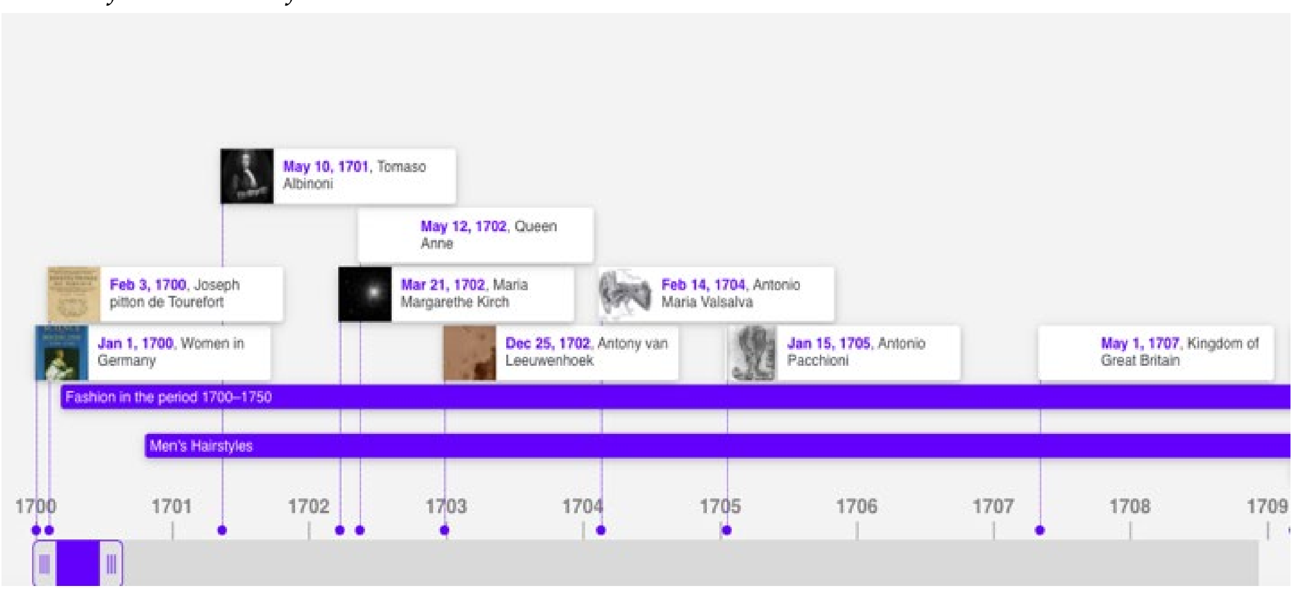
The versatility and ability to mobilize information across a large scale was cited by another TC as an effective way to convey knowledge and understanding:

It worked well, because you type in your own little "blurb" about whatever it is and then you can link it to another page. You can upload videos and pictures and stuff. So, it worked well. You could have that first brief information and then if anyone wants further information, then there's a link to more details … in art, music, religion.

The aforementioned reflections are further captured in Figure 3, which features a screen capture of a digital timeline, created with Timetoast, demonstrating a multitude of different possibilities for representing and disseminating information. This timeline is modelled linearly but each entry is hyperlinked with additional information and details, enabling readers to learn more about each of the entries.

Figure 3

A Screen Capture of a Digital Timeline Created with Timetoast Illustrating a Multitude of Possibilities for Representing and Disseminating Information Showcasing the Sociocultural Milieu of the Nature of Science



New Knowledge and Understanding of Technology

TCs believed their experiences helped to inform their understanding of technology and its evolution over time. Quite unanimously, TCs acknowledged that in developing their digital timelines they were able to identify trends of technological improvement and recognize the growing presence of technological devices. One TC remarked:

> Technology is also ever changing. We looked at the first phone that was made and it was a huge, huge phone, and then we're looking at today's teenager, we have the iPods, all these small skinny cell phones that do the same job as a telephone would and even more.

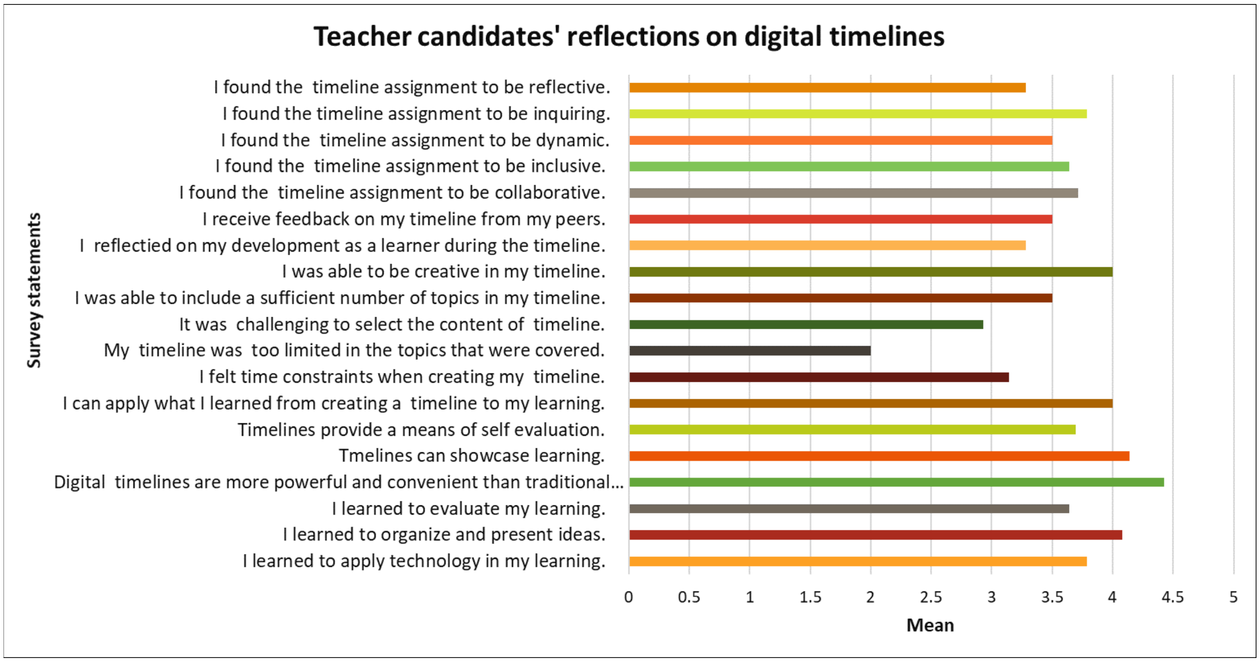
This notion was echoed by another TC who commented that the technology itself not only improves as time progresses, but its presence and consumption also increase, referencing the widespread popularity of technology products (e.g., cell phones, tablet, etc.) and their integration into practice (apps to engage and interact, e.g., Mentimeter, Kahoot!).

Reflecting on Digital Timelines: Affordances and Constraints

Figure 4 captures TCs' reflections on developing their digital timelines. There are notable affordances including the fact that the digital timelines fostered creativity, are more powerful and convenient, and can enhance learning. Constraints included time and resource selection.

Figure 4

Teacher Candidates' Reflections on Digital Timelines



Enhanced Quality of Work

In reflecting on the differences between paper-based versus digital-based formats to represent timelines, TCs overwhelmingly agreed that the digital timelines are more powerful and convenient than traditional paper-based formats (Figure 4). TCs identified one significant benefit from creating digital timelines—the presence of digital technology enhanced the quality of their work. During the interviews, one TC discussed that unlike paper-based counterparts, the possibility of adding multimodal components (e.g., music and format transitions) to digital timelines captivated the attention of their audience, thus allowing them to unpack larger sources of information without feeling intimidated.

Figure 5 highlights an example of a digital timeline created in Prezi that uses the software's technological features and resources to present scientific discoveries in a unique layout, with non-linear transitions and various sources of multimedia (e.g., images, videos) embedded. For example, one of the frames highlights James Watson, Francis Crick, and Maurice Wilkins' Nobel Prize for discovering the structure of DNA. Although not credited, Rosalind Franklin's work was central to the understanding of the molecular structure of DNA. Together, the images of Rosalind Franklin, Photo 51 (taken by Franklin, which provided the vital clue to the double helix structure of DNA), an illustration of DNA, accompanying text, and a video interview with James Watson and Francis Crick convey quite effectively the context of the discovery, as well as the players and elements of the scientific enterprise.

Figure 5

A Digital Timeline, Created in Prezi, that Uses the Website's Digital Tools to Present Scientific Discoveries in a Unique Layout, Embedded with Various Multimedia

Digital tools and elements captured in Figure 5 were mentioned by a TC who acknowledged the visual potential of paper-based formats but outlined the advantage of digital-based timelines in the interview:

> [The] paper format is still visual, but it's not as catchy as a digital one. And I think we have kind of moved away, hopefully, from the paper formats, just because technology is [in] everyday use. So why wouldn't you use [them]? You

> can do a lot more with the digital format than you would be able to do with the paper format. There are videos, you could include music if you wanted to. You could make it a lot more presentable and learn a lot more through the digital format than you would from the paper format about the scientists, about discoveries.

Another TC discussed the practicality of using digital tools by stating that, "digitally, it's a lot more feasible, only because sometimes you can have a lot of events happening during a time period, so having something digital and not having a lot of paper, is more of an advantage. Visually, definitely digitals really help".

User-Friendly and Effective Capabilities of Website and Application Technology

Positive endorsements for digital technology from TCs pertained to the websites and applications that were used to construct the timelines. According to the TCs, the websites and applications were paramount in terms of making certain aspects of their work both less time consuming and less difficult to navigate. One TC noted:

> If it's digital, you can spend less time worrying about the creativity of it, because you can just click a button and it sort of just changes everything. So, you are spending more time on things that are relevant as you are becoming more familiar with programs and stuff that are available to you.

Similarly, another TC discussed the software they used and how it simplified the creative process, commenting:

> You don't need to have as much art to construct something digitally as you do on paper. So, you can make something look really great online and you don't need to be an artist. While, constructing something on paper is a lot harder to make it … you need to have some pretty good skills to make it look good on paper.

In all cases, the TCs addressed the affordances of certain presentation and timeline-based technologies and went on to articulate how these technologies can shift the creative process when creating digital timelines.

Increasing Engagement and Motivation

Various elements were embedded in the digital timelines to engage and motivate the audience. For example, Figure 6 (left side) illustrates the sending of the first wireless radio signal along with a link to watch a debate about this controversial discovery. The screen shot on the right side in Figure 6 highlights the scientific discovery of four blood groups in 1901 with a link to play the Blood Typing game in which a player can engage with the game and learn about different blood groups, antigens and antibodies, blood typing, blood transfusions, and consequences of receiving the wrong blood type in a transfusion. Both examples demonstrate opportunities for the audience to interact and become engaged in deeper learning about contexts surrounding scientific discoveries.

Figure 6

Screenshots of a Digital Timeline Focusing on the 1900s

Note. The timeline illustrates (a) the first wireless radio signal with a link to a debate on this controversial discovery (left side), and (b) the discovery of four blood groups in 1901 with a link to play the blood typing game (right side).

Overall, several TCs felt that the decision to create their timelines digitally impacted how engaged they were with the assignment. This was conveyed in a TC's response to a question about their motivation level:

> The fact that I had to learn about the software [affected motivation] … It got me intrigued once I was able to have a basic understanding of the program. It was

> just really all about how do I want it made out, what do I want to show here and there? So, it was really exciting.

This was paralleled by another TC's statement about their motivation:

> You can make those [digital] changes really easy and continue to do that. Changing pictures … but on paper, once you do put a picture down and glue it there, then it's stuck, and you can't make any changes [leading to demotivation].

It is evident that TCs embraced the opportunity to work more intimately with the new types of digital technology that accompanied websites and applications, such as Prezi, Timetoast, and Tiki-Toki, as well as incorporating voice, printed text, digital games, debates, video, interviews, etc., in their digital timelines. Through these experiences, they were able to not only create timelines that matched their intended vision but also do so in a way that did not require any sort of prior or specific experience, competencies, or skills. In fact, it can be argued that, based on their reflections on their experiences with digital technology, they may have, in actuality, increased the breadth of their existing skillset and developed more comfort with unfamiliar digital technological devices and software through the process of creating digital timelines (Figure 4).

Discussion, Implications, and Limitations

In this study, TCs engaged in a knowledge construction process collaboratively. Through the course assignments TCs were provided opportunities to locate and consume digital content, create digital content, and communicate digital content (Spires et al., 2012). In terms of developing technological knowledge and skills, TCs reported that the course assignments unquestionably impacted their technological literacy and self-efficacy (Skaalvik & Skaalvik, 2008) in a positive manner. It is evident that TCs felt that they learned about technology, how to use new equipment, and how to use new programs or improve their usage of familiar programs. Some TCs experienced challenges; however, this did not dissuade them from seeking out peer and instructor support to become familiar with the equipment and programs and how to use them effectively in order to complete their assignments. One noteworthy finding is the fact that TCs felt that they learned to apply technology in teaching and learning (Figure 4). Furthermore, there was a positive trend towards using technology in their future practices. TCs' survey responses demonstrated heightened technological literacy in terms of digital competence (skills), digital usage (professional and discipline application), and digital transformation (innovation and creativity) (Belshaw, 2011).

Taken together, the aforementioned findings suggest that TCs' TPACK (Pringle et al., 2015) was enhanced as a result of engaging with digital technologies in the course by creating digital timelines. TCs demonstrated the interconnectedness of TK, CK, and PK through their digital timelines as they showcased the history of scientific discoveries. The digital timelines were rich with science content, as well as accompanying pedagogical approaches and technological knowledge. Despite sharing positive reflections about the role of technology in teaching and learning, there is no guarantee that TCs will in fact implement digital technologies in their future practices, as opportunities to observe TCs applying their knowledge of each TPACK domain while teaching was beyond the scope of this research. TCs' ability to teach effectively in their future practices will be defined by the complex interactions among TK, CK, and PK in specific contexts (Koehler & Mishra, 2009).

While focusing on the existing level and measure of TCs' digital competencies was an overarching interest of this study, TCs' experiences with creating digital timelines suggest that there were no additional nor specific digital skills or competencies needed to produce informative and effective digital timelines. As TCs' reflections suggest, the accessibility and user-friendliness of the websites and programs they used enabled them to produce digital timelines that conveyed scientific discoveries with high degrees of creativity, clarity, and context. TCs reported that the digital timelines attracted and maintained the interest and engagement of their peers, a finding corroborated by Wilson et al. (2007).

In actualizing the potential of their timelines, TCs were able to demonstrate the full scope of multiple representations (Schnotz, 2014) that comprise effective and engaging digital timelines. Across the numerous examples of digital timelines that were either shared or discussed, it was evident that TCs could successfully use any combination of text, image, video, sound and audio, spatial, or visual components to convey the meaning behind selected scientific discoveries and could do so without any major hindrance or difficulty. TCs were able to represent their timeline discoveries using both linear or non-linear formats and sequences, and embed different multimodal components to accompany their choice, meaning that each timeline was unique and original in how it communicated content and how it was interpreted by its audience (Cope & Kalantzis, 2000; Martin & Grudziecki, 2006).

In reflecting on their experiences, TCs noted many beneficial effects associated with creating and using digital timelines in the course. An increase in positive attitudes towards technology is one such benefit, as indicated by multiple quotes from interview data referencing TCs' enjoyment and engagement while utilizing various timeline software. Additionally, the comments and quotes in question may also indicate that TCs would be more inclined to use the technology again and, perhaps, venture into using new, unfamiliar technologies, thus signifying potential increased use of technology in their future practice. Aldunate and Nussbaum (2013) found that teachers who incorporated technologies early were more likely to continue with more complicated systems rather than abandoning them altogether. With this understanding, both the increased use of and positive attitudes towards technology would suggest that global competencies and 21st century skills, especially critical thinking and communication, can potentially be promoted and fostered through similar experiences with digital technology in the future (Ontario Ministry of Education [OME], 2016; Zhang & Martinovic, 2008).

Despite the fact that using digital technologies as part of the educational environment fits into the philosophy of active learning and constructivism, it poses a tremendous challenge for teaching and learning in different contexts, specifically those that may not have access. Consequently, this decreases an individual's access to social opportunity. Thus, research that promotes a deeper understanding of where knowledge gaps exist in the research base around the impact of digital technology on teaching and learning in these communities is warranted. Findings, including gaps and barriers, will make significant contributions to our understanding of cultural- and socially-informed digital literacy and can inform educators, researchers, and policy makers as to benefits and challenges of implementing digital and technology-based projects in different contexts.

It may be of interest to explore, and potentially measure, the efficacy of other digital technological tools and resources in addressing aims similar to those of this paper. That is, exploring other digital tools and resources that incorporate and demonstrate multiple representations in ways that provide clarity and engagement for learners beyond those demonstrated through digital timelines. In addition, teacher education programs and their promotion and implementation of digital technologies as pedagogical tools is another avenue worth exploring, given this is where TCs' attitude towards and interest in digital technology can be impacted. On that note, additional studies examining the effectiveness of digital timelines with participants in a variety of disciplines would potentially provide further validity and reliability for this particular phenomena. Moreover, additional studies can potentially provide a more accurate glance at the relationship between TCs and digital timelines, as well as the relationship between TCs and digital tools and resources as a whole.

Conclusions

In this study, the majority of TCs felt that they had acquired the necessary general technological skills for creating their digital timelines, with a few TCs reporting significant difficulties using the necessary computer equipment or software. TCs noted a number of affordances and constraints associated with the development and implementation of digital timelines. TCs preferred digital timelines over traditional formats as they (a) are more powerful, dynamic, and convenient than traditional [paper and pencil] poster media; (b) showcase learning more effectively; (c) allow for the incorporation of an assortment of topics and disciplines, and digital tools to enhance learning said topics; (d) promote creativity; and (e) encourage collaboration.

In terms of creativity, TCs felt that they were encouraged to be creative by including audio, digital tools, YouTube videos, and digital games, to name a few. Findings indicate TCs experienced: (a) enhanced technological literacy in terms of learning about technology, software programs, and equipment; (b) the process of knowledge construction and dissemination; (c) self-directed learning; (d) personalized learning pedagogy; and (e) heightened self-efficacy. TCs also reported affective outcomes including enhanced motivation, engagement, confidence, interest, and pride in their experiences developing digital timelines.

Despite the successes experienced, TCs cited a number of potential challenges to implementing digital literacies in the classroom, including the fact that (a) teachers need to be trained in order to effectively utilize digital literacies and achieve success in terms of developing learning communities in the classroom; (b) digital literacies should be introduced in the lower grades, thus allowing students to become “more comfortable and confident when using these technologies” as students who are not “tech savvy” might be resistant to learning through “new” technologies; and (c) access to computers is the greatest obstacle to implementing digital literacies, a finding consistent with research (OECD, 2013), which maintain that despite the ubiquity to computers in the home, student access to computers at school is still limited. Other challenges include the choice of content for the scientific timelines, given the enormous amount of digital resources available online. Similarly, the variation in choice of digital literacies available posed a challenge as some TCs felt that "their choice of representation" did not always coincide with what was being promoted in their host school, a challenge raised by Jewitt (2008) around knowledge construction.

Results of this study may contribute to the information available to educators and curriculum consultants about developing learning communities through the integration of activities involving digital literacies and products of personal creativity that vary according to students' unique learning styles. As well, the provision and use of digital timelines may assist TCs in helping students develop global competencies and 21st century skills, enhance teachers' and students' scientific and technological literacy, and improve attitudes toward teaching and learning in technology enriched environments.

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