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ORIGINAL PAPER

Computational Thinking and Media & Information Literacy: An Integrated Approach to Teaching Twenty-First Century Skills

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Abstract Developing students' 21st century skills, including creativity, critical thinking, and problem solving, has been a prevailing concern in our globalized and hyper-connected society. One of the key components for students to accomplish this is to take part in today's participatory culture, which involves becoming creators of knowledge rather than being passive consumers of information. The advancement and accessibility of computing technologies has the potential to engage students in this process. Drawing from the recent publication of two educational frameworks in the fields of computational thinking and media & information literacy and from their practical applications, this article proposes an integrated approach to develop students' 21st century skills that supports educators' integration of 21st century skills in the classroom.

Keywords Computational thinking · Consilience · Media & information literacy · Participatory culture · Scratch · Twenty-first century skills

According to a recent Pew Research Center survey, 92 % of American teenagers go online on a daily basis, including 24 % of them "almost constantly" (Lenhart 2015, p.16). These numbers embody the increasing participation of teens in digital media over the past few years, principally characterized by communication on social media such as blogs, social networks, forums, or video sharing websites (Boulianne 2015). This online engagement is also illustrative of what Jenkins (2006, 2009) called our era's "participatory culture," a culture where, thanks to technology and digital media, Internet users have the opportunity to become creators of knowledge instead of passive consumers of information (Buckingham 2007; Lankshear and Knobel 2008). A key challenge of this participatory culture, however, is the digital gap that divides individuals who possess the ability to produce and distribute self-created content, and those who do not have the competencies required to take part in said participatory culture (Jenkins 2009). In this context, many scholars and policy-makers see educators as central to addressing such disparity by preparing students to gain the experiences, skills and knowledge to be successful in the 21st century (Jenkins 2009; Davies 2011; NRC 2011; Wilson et al. 2013). These abilities can be summed up by two main skills: creativity and critical analysis (Buckingham 2015; Jenkins 2009). In other words, "it is about making media as well as analyzing media" (Buckingham 2015, p.10). That is, in order to take part in today's participatory culture, career-ready students should know how to create digital content, and they should know how to critically analyze digital materials as well.

Although the current landscape in education emphasizes the importance of developing students' 21st century skills through a variety of standards (Governors Association Center for Best Practices 2010; ISTE 2015; NGSS 2013; Partnership for 21st century, 2014), little has been done to implement computing technologies in a way that enhances creativity and critical thinking across the United States K-12 curriculum, compared to efforts in European countries to include either computing or digital media literacies in the mainstream curriculum (Tucker 2003; Livingstone 2011; McDougall and Livingstone 2014; Mommers 2014). To address this gap and to support teachers' integration of 21st century skills in the classroom, the present paper highlights two initiatives that connect creativity with

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critical analysis through two approaches to 21st century skills: computational thinking, and media & information literacy. While practices in computational thinking and media & information literacy each address technology from a different pedagogical perspectives, they share the same goal: to make students skilled users of digital tools, whether through the creation of content thanks to programming and coding, or through the analysis of such content thanks to analytical and critical thinking. In this paper, we argue that taken together, these practices provide an all-encompassing continuum of 21st century skills—from creativity to critical analysis—that can strengthen the technological and analytical abilities that students need to become active citizens in their digital environments.

The purpose behind merging two seemingly disparate ways of thinking into a continuum is two-fold. First, it bridges artificial divides between disciplines (i.e., sciences and humanities) in order to consider multiple paths towards fostering 21st century thinking (Carroll 2014). And second, it reinforces the need for consilience and integration in 21st century education (Goodwin and Sommervold 2012). Consilience is a term that biologist E.O. Wilson (1999) used to allude to the integration of knowledge between disciplines and the bringing together of ideas to strengthen expertise. Because our world is more globalized than ever, 21st century skills like critical thinking, creativity, and communication require a consilient or integrated approach to education where different disciplines come together to bolster students' academic and personal skills (Goodwin and Sommervold 2012).

A number of scholars have indeed suggested that principles from computer science should be integrated across school subjects (Barr and Stephenson 2011; National research council 2010; Perković et al. 2010; Qualls and Sherrell 2010; Wing 2006; Yadav et al. 2014). Similarly, efforts to incorporate media literacy or information literacy in educational settings have also been pursued (Eisenberg et al. 2004; Felini 2015; Hobbs and Jensen 2009; Thomas 2004). The section below describes how merging computational thinking (CT) and media & information literacy (MIL) can help support students' 21st century skills and citizenship and how, together, they can equip students with the complementary skills to become active as well as reflective participants in their digital culture. We then draw upon two specific pedagogical frameworks that emphasize creativity and critical analysis skills (College Board 2014; Grizzle et al. 2014), and illustrate their compatibility through the example of Scratch, a programming language and online community for teachers aiming to develop students' 21st century digital skills.

Computational Thinking and Media & Information Literacy as 21st Century Skills

Twenty-first century skills are largely dependent on advances in technology and on the unique affordances of the Internet (ISTE 2015; P21, 2014). Nevertheless, while access to technology is an important aspect for students to gain 21st century competencies (Jenkins 2009), closing the participation gap essentially relies on teaching the skills that will allow students to create and share information with others and to critically assess others' content (Frau-Meigs 2007; Gee 2004; Grizzle et al. 2014; Wartella et al. 2000). To address this participation gap and teach the array of skills echoed by the aforementioned standards, computational thinking and media & information literacy can emphasize students' digital creativity and critical awareness in a globalized and hyper-connected world (College Board 2014; Grizzle et al. 2014).

Computational Thinking

Recently there has been an emphasis on teaching students how to think like a computer scientist (i.e., computational thinking) and on the need to highlight the principles of computer science at the K-12 level (Barr and Stephenson; 2011; College Board 2014; Wing 2006; Yadav, et al. 2014). While computer science has been defined as the study of computation and its theoretical underpinnings (Brookshear 1997), computational thinking is composed of concepts fundamental to computer science, along with the intellectual skills that are needed for algorithmic thinking, pattern recognition, abstraction, and decomposition (Grover and Pea 2013; Wing 2006; 2008). With the intention to introduce computational thinking to all students, the College Board (2014) is piloting an Advanced Placement Computer Science Principles curriculum framework (CSP), which aims to highlight computational thinking practices in everyday life through computing technologies. Instead of providing a traditional computer science course focused on programming, the CSP curriculum framework intends to be an approachable course to teach the foundational ideas of computing as well as computational thinking concepts and practices (College Board 2014). The course targets skills that foster creativity by using technology to solve computational problems. The course also focuses on developing students' 21st century skills, such as analyzing and representing data, understanding how the Internet functions, and grasping how computing impacts people and society. Within this pedagogical framework, developing 21st century skills allows students to be college and career ready, and to "develop effective communication and collaboration skills, working individually and collaboratively to solve problems, and discussing and writing about the importance of these problems and the impacts to their community, society, and the world" (College Board 2014, p. 1).

The CSP framework is centered around seven big ideas of computer science and computational thinking practices: creativity, abstraction, data and information, algorithms, programming, the Internet, and global impact. In addition to these computational thinking skills and practices, the CSP

framework also aims for students to collaborate and communicate with others to solve problems and to understand the impact of these problems both on an individual and on a global level (College Board 2014). The CSP framework thus recognizes the relevance of digital skills in the context of the broader social impact of the Internet, an issue that overlaps with the concept of media & information literacy (Wilson et al. 2013).

Media & Information Literacy

Media & information literacy is an umbrella term coined by UNESCO (Wilson et al. 2013) that joins media literacy with information literacy while emphasizing the importance of critical analytical skills for media and information consumers. For UNESCO, an information-literate individual should know how to access and evaluate information, but also how to use it in an ethical manner; and a media-literate person should understand the functions of media and engage with the latter for self-expression (Wilson et al. 2013). Recently, UNESCO (Wilson et al. 2013; Grizzle et al. 2014) published a media & information literacy framework in which it defined the critical and analytical skills needed for digital users to evaluate information and to recognize the power of media in our daily lives. The UNESCO framework (Grizzle et al. 2014) also defined 21st century skills as the combination of various digital literacies aiming to empower users through critical and communicative skills (Wilson et al. 2013).

In its framework, UNESCO (Grizzle et al. 2014) highlighted the importance of computing technologies—in particular the Internet—for media & information literacy in today's globalized and connected world. Although approaching 21st century skills from different perspectives, both the CSP framework (College Board 2014) and the UNESCO framework (Grizzle et al. 2014) recognize the importance of the societal impacts of technology, as well as the relevance of developing students' skills in computing technologies. As a result, a consilient approach to teaching 21st century skills could integrate those complementary sets of skills to provide students with a comprehensive understanding of the role of computing technologies in today's society. The table below encapsulates the complementary concepts that CT and MIL present from the perspective of 21st century skills and citizenship Table 1.

An Integrated Approach to 21st Century Skills

To illustrate an integrated approach to 21st century skills that bridges creative and critical skills, this section discusses the complementary nature of the College Board CSP framework and the UNESCO framework. Specifically, we outline the commonalities between the CSP's seven big ideas and UNESCO's competencies. We then use Scratch, a programming language and online community of storytellers, to tie these skills with participatory practices on the Internet. We argue that taken together, these complementary skills could increase students' critical abilities to understand how Internet content is created as well as their own capacity to, in turn, participate in the creation of digital content.

Big Idea 1. Creativity

The first big idea that the CSP curriculum framework espouses is that computing is a creative and innovative activity (College Board 2014). Specifically, the CSP framework suggests that computing allows using creative development processes to create computational artifacts or to solve problems instead of simply teaching students a single programming language. Through the creation of artifacts and knowledge, then, computing can help students use technology to creatively express themselves (College Board 2014). In a similar vein, the UNESCO framework (Grizzle et al. 2014) also promotes creativity in the form of self-expression. Through MIL, UNESCO (Grizzle et al. 2014) aims to involve citizens in the production of media and information, particularly on the Internet. The framework, however, emphasizes that creativity also comes with issues that digital users of information should acknowledge, such as copyright and intellectual property (Grizzle et al. 2014). The combination of these two different approaches to the creative process should therefore encourage students' expression as well as their ethical use of information.

Big Idea 2. Abstraction

Abstraction, or the reduction of information to focus on relevant details, is a central problem solving approach that computer scientists use. Abstraction allows for the representation of complex systems and models them to solve problems using computational systems. Through abstraction, students can simplify complex data in order to manipulate it under different forms (College Board 2014). For UNESCO, abstraction is encapsulated within the concept of synthesis, that is, abstracting ideas from content. To be information literate thus means to be able to make decisions based on the knowledge abstracted from specific information (Grizzle et al. 2014). Together, both frameworks place problem solving and decision making as key concepts for the development of 21st century skills.

Big Idea 3. Data and Information

Data and information as a form of knowledge creation is a central focus in both the CSP (College Board 2014) and UNESCO (Grizzle et al. 2014) frameworks. Computing permits the processing and visualization of large amount of raw data to create information (College Board 2014), and

Table 1 CT and MIL

Computational thinking College board CSP framework	Media & information literacy UNESCO MIL framework
Creativity	Developing computational artifacts including, media
Abstraction	Synthesize information to focus on key ideas
Data and information	Access and evaluate information to develop new understandings
Algorithms	Develop an understanding of how algorithms are used to deliver content online
Programming	Develop an understanding of programs behind the media platforms
The Internet	Understand privacy issues to communicate safely with others
Global impact	Promoting access to media and information to embower users

information literacy allows users to critically assess the produced information (Grizzle et al. 2014). Data and information is the concept that best encapsulates the overlap between the two frameworks, as it represents the juncture between the computational thinking skills of data representation and visualization, and the social and critical skills of media & information literacy.

Big Idea 4. Algorithms

One of the seven big ideas of the AP Computer Science Principles framework involves students knowing how to develop, use, and analyze algorithms. Algorithms are "precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages" (College Board 2014, p. 17). But while the CSP framework focuses on the use and creation of algorithms to solve computational problems, the MIL framework (Grizzle et al. 2014) focuses on the analytical aspect of interacting with those algorithms on the other side of the computer. That is, it aims to provide students with the skills to understand and critically assess the content that appears on the screen, like how commercial advertisers use algorithms to target users' interests based on their digital footprint for instance (Gurram et al. 2014). Algorithms can be perceived from both perspectives as heuristics available for students to increase understanding and support the creation and evaluation of digital content.

Big Idea 5. Programming

Programming involves the execution of algorithms to create digital artifacts, including music, visualizations, websites, etc.… The CSP framework focuses on having students develop computer programs to enable their creative expression, satisfy personal curiosity, or create new knowledge (College Board 2014). Similarly, UNESCO (Grizzle et al. 2014) also recognizes that information and communications technologies and digital skills are essential to produce content. Whether visual, textual, audio, or multimodal, possessing digital skills to communicate ideas is crucial to participate in today's Internet era (Grizzle et al. 2014; Jenkins 2009). Increasingly, citizens are more and more responsible for the generation of knowledge, as can be seen through the example of user-generated content (e.g., videos, apps, websites, blogs, online games, social networks, etc.). From that perspective, programming allows the creation of the platforms and content that enables individuals to be creative and communicate their ideas, while MIL supplies the social skills needed to ethically share created knowledge to an audience appropriate for that medium.

Big Idea 6. The Internet

Internet plays a key role in today's society. College Board (2014) aims to prepare its students to understand how the Internet, its networks, and its systems, operate in order to support communication and collaboration. Comparably, the UNESCO framework (Grizzle et al. 2014) argues that users should be empowered by acquiring the skills and knowledge to critically interact with all forms of media and information online. Both frameworks also highlight the importance of online security (College Board 2014; Grizzle et al. 2014). While the CSP curriculum framework (College Board 2014) prepares students to address security problems such as cyber-warfare or cyber-crime by analyzing antivirus software and access to private data from a technical point of view, UNESCO is concerned with issues of personal security, and addresses matters of identity theft, phishing or cyber-bullying, by equipping users with the necessary skills to combat those problems.

Big Idea 7. Global Impact

Finally, the last big idea expressed by College Board (2014) is the global impact of computing. Technology has vastly impacted the way we communicate, collaborate, or solve problems (College Board 2014). Students following the CSP

framework will be exposed to both the beneficial and the harmful effects of computing on people and society. These include the legal and ethical concerns of online streaming or information access, privacy and security, anonymity, copyright, or targeted advertising. Overall, the curriculum framework aims to highlight the connections between computing and broader economic, social and cultural contexts. In a similar manner, the UNESCO framework (Grizzle et al. 2014) shows how media & information literacy can empower digital users while respecting and promoting others' rights through ethical responsibility and global citizenship.

Given the substantial overlap between computational thinking and media & information literacy frameworks, the question remains: How can we engage students and teachers in these concepts? One idea is to develop those skills through Scratch, a visual programming environment that allows learners to move from being passive consumers to active creators of digital content.

Scratch: Promoting CT and MIL

Scratch is a programming tool that illustrates a promising approach to introducing students to aspects of computational thinking as well as media information literacy. Scratch is a programming tool for first-time programmers that values digital fluency through the creation of digital artifacts such as videos, stories, music, simulations, interactive art, or games (Resnick et al. 2009). Scratch programs are made of blocks that snap together like a puzzle while emphasizing computing concepts and computational thinking (Resnick et al. 2009). Because users share their artifacts online, Scratch is also an active online community, which can be particularly engaging for students in middle and high school (Lee 2009), as well as for their teachers who can benefit from instructional support through the ScratchEd online community (Brennan 2009). The advantage of Scratch as an educational tool for 21st century skills is that it promotes both the technical as well as the social and communicative aspects of computing (Brennan 2014). Teachers can thus use the platform as a segue to simultaneously teach computational thinking through the seven big ideas of computing, as well as critical analysis through the media & information literacy principles mentioned above.

Scratch can support the growth of the competencies that will help students further the development of their 21st century skills, such as CT and MIL. Armoni et al. (2015) found that in addition to higher levels of motivation and self-efficacy, students who had been exposed to Scratch in middle school also displayed the abilities that facilitated the transition to learning more professional textual programming languages (e.g., C# or Java). Exposing students to Scratch as a beginning step could, therefore, expose them to the programming experience needed to develop both the knowledge and the interest in pursuing more advanced computer science courses. In addition, Peppler et al.'s work (2014) indicated that using Scratch can also promote students' acquisition of media literacy, arguing that exposing them to new digital tools and networks can improve their literacy practices, social interaction, and critical appreciation of media. Specifically, Scratch provides students with opportunities to create and customize their own characters and scenarios, while also allowing them to evaluate the variety of projects that other users have shared online.

For this reason, Scratch offers teachers a way to advocate for students' engagement with technology and to bolster their development as informed 21st century citizens. Because Scratch is a flexible instructional platform, teachers can find ways to present its appeal to a variety of students, regardless of their interests or abilities in digital media or computing. Shelby-Caffey et al. (2014) explained that indeed, participation in new media like Scratch can consolidate both students' analytical and technological abilities. Merging those skills could help avoiding the cycle contributing to the expansion of the digital participation gap in which "those with higher technological competence tend to grow in their interest and skill level, while the skill level and interest of those with low technological competence and interest further diminishes" (Shelby-Caffey et al. 2014, p. 197). To help educators achieve this purpose, ScratchEd administrators have created an online curriculum guide as well as a guide to creative computing to help teachers understand the platform and adapt its functions to their instructional needs. Additionally, the online ScratchEd community offers support to K-12 teachers in the creation of lesson plans or activities that can be beneficial to their students based on their ability levels or area of study.

Overall, the ideas advanced through computational thinking (College Board 2014) and media & information literacy (Grizzle et al. 2014) propose a balance between the technical and the critical skills that students need for their professional and personal development in the 21st century. Scratch offers one alternative to bridge CT and MIL in an integrated approach that promotes 21st century skills. It also offers teachers the option to address 21st century skills from different angles, to expose all students to a variety of digital skills and experiences, and to challenge the precepts of the participation gap (Jenkins 2009) in today's globalized society.

Conclusion

The global impact of technology has implications not only for citizenship in the 21st century, but also for the role that educators play in teaching the skills that students need to acquire to become active citizens in their 21st century participatory culture. A digital 21st century citizenship is complex and multifaceted (Cogan et al. 2014), and requires the youth to be well educated and informed (College Board 2014), engaged and

active (P21, 2014), ethically responsible (Lankshear and Knobel 2008), and open to intercultural dialogue (Grizzle et al. 2014). Teachers play a key role in promoting this 21st century citizenship, and they need to adapt to being 21st century teachers as well (Appleyard and McLean 2011; Devlin-Foltz 2010; Guo 2014; McLean et al. 2006; Wilson et al. 2013). The complementary relationship between computational thinking and media & information literacy can provide teachers with a comprehensive set of skills to allow students to both critically navigate and creatively produce digital content.

By raising awareness about an integrated view of 21st century skills, educators, teacher educators, and other professionals in the field of education will benefit from learning about the array of skills that will allow students to evolve across a spectrum of professional and personal abilities while developing and promoting digital citizenship (Hollandsworth et al. 2011). In our 21st century globalized and hyper-connected world, these are the students who will bridge the digital gap and use the affordances of today's technologies to address, communicate, and challenge the contemporary issues that pervade our digital worlds.

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