

Techno-mathematical literacies in digital age: Which categories are importance for teachers?

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Abstract

Nowadays, digital technologies development potentially have changed on teaching and learning activities and demands teachers' competencies and literacy. In this study, narrative review is used to identify the types of Techno-mathematical Literacy (TmL) that the teachers need to acquire in this digital age. There are seven categories of TmL studied, namely: data literacy, ability to use computer software, communication skills, ability to analyze errors, ability to interpret numbers, creativity, and drawing skills. The results show that the seven categories are crucial for teachers to execute their role in this highly demanding era. These results also indicate that techno-mathematical literacy needs to be applied in the field of teacher education to adequately equip the students with the skills required in the workplace. The result also suggested that teachers need to be encouraged to develop their instructional design in the attempt to enhance students' techno-mathematical literacy.

Keywords: data literacy, digital age, digital literacy, techno-mathematical literacy, teachers

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INTRODUCTION

Over the last decade, many educators and policymakers believe that digital technologies can potentially revolutionize the education system (Blackwell et al., 2014; Vucaj, 2020). Some institutions also were investing in new technologies to deliver educational experiences and exploring how the sector might respond to the future needs of industry and jobs (Bonfield et al., 2020). Furthermore, research in learning and information technology is often lacking in the broadest way to define this field, and often fails to take into account the transformational aspects of these dramatic changes (Fischer et al., 2020). In another words, educators and policymakers do not solely concern on the technology, but on how technology can change the ways of teaching and learning. Moreover, technology is considered merely as tool that will be dysfunctional without any skills and literacy to use it. Computer literacy, media literacy, digital literacy, and digital competence are terms that are often used in examining the need to handle technology in the digital age (Krumsvik, 2008).

Digital technologies, including hardware, applications, and support infrastructure, have been introduced into school systems around the world and influence the work of teachers (Starkey, 2020). Teachers should become fluent in new technologies in order to use new methods of teaching in the digital world and improve the learning and classroom environment (Keshavarz & Ghoneim, 2021). This reform faces many challenges, including the social and economic challenges of reforms and training, particularly, with digital technologies that evolve rapidly and constantly change the landscape of professional and personal life (Tan et al., 2021). Nevertheless, research has shown a significant gap between these views and how technology is actually used in educational practices (Voogt et al., 2013). Blackwell et al. (2013) have explored how teachers' beliefs and attitudes can influence low technology use in their daily activities. In addition, age is also one of many factors that can influence teachers on technology use. In our view, currently many teachers are still dominated by digital immigrants rather than digital native. According to Prenksy (2001) digital native is someone who was born around 1980 and after, while digital immigrant is someone who was born before 1980. For example, many teachers consider themselves too old, uninterested or incompetent to integrate digital technology into their teaching (Thomas, 2011; Perrota, 2013).

Furthermore, many higher educations have not fully accepted digital literacy as basic literacy which is equivalent to reading, writing and numeracy (Murray & Perez, 2014). In fact, digital literacy is indispensable to equip the students with the skills required in the workplace. Digital literacy has also become a concern of

UNESCO (2011) and it has been considered as an ICT competency framework that is required for professional teachers in the digital age.

To date, research on mathematical skills with technology has been initiated by Celia Hoyles et al in 2002 (Jacinto & Carreira, 2016). Hoyles (2002) proposed a concept under the term "mathematical literacy" stating that one of the conditions for the success of workplace performance is mathematical skills. After that, Kent et al (2005a) discovered a concept with the term "techno-mathematical literacy" as a way of thinking about mathematics which is part of modern IT-based work practices that are increasingly used.

Moreover, literacy is a term used to assess a person's abilities. The connotation of the term literacy reflects a person's ability to read, write, and use the basis of mathematics (Ritz, 2011). Based on these explanations, Techno-mathematical Literacy (TmL) is a connotation about one's ability to use technology-assisted mathematical skills. Despite the mathematical words in the term TmL, this connotation is not specifically related to the field of mathematics but also applies to other fields of science.

Techno-mathematical literacy research on mathematical skills, statistics, and technology in the workplace has been reviewed by Kent et al. (2005b). The study focused more on the techno-mathematical literacy of workers in three industrial sectors (pharmaceutical, packaging, and retail financial services) and they focus on employees at "intermediate" skill level, typically non-degrees of the A level (ie. high school) or equivalent qualifications who work in the manufacturing industry as qualified operators or supervisors, or in the service industry (such as banking) as sales agents or customer enquiry agents. Likewise, research on what aspects of techno-mathematical literacy are needed by engineers in the future has been carried out by van der Wal et al. (2017). However, studies of the importance of techno-mathematical literacy for teachers in the digital age have not been found based on document searches through online search engines. Thus, the study of the importance of techno-mathematical literacy for teachers in the digital age needs to be explored.

METHOD

Adapting a narrative review method, this study investigated the aspects of Techno-mathematical Literacy (TmL) that the teachers need to acquire in the digital age as it appears from research observation. The source used as the study material is the TmL category adapted from van der Wal et al (2017). There are seven categories TmL studied, namely: data literacy, ability to use computer software, communication skills, ability to analyze errors, ability to interpret numbers, creativity, and drawing skills. The seven TmL categories are presented in Table 1.

Table 1. Techno-mathematical literacy categories adapted from van der wal et al. (2017)

No.	TmL category	Description
1.	Data Literacy	The ability to analyse and interpret technical data and graphical representations, draw conclusions and take action accordingly
2.	Technical software skills	The ability to use professional software, e.g. Excel™, as a calculation tool
3.	Technical communication skills	The ability to communicate technical information with colleagues, customers, supervisors and other parties
4.	Sense of error	The ability to check and verify data and detect errors
5.	Sense of number	The ability to handle and interpret numbers sensibly
6.	Technical creativity	The ability to produce creative solutions to puzzles and problems (by using, e.g. cleverness or experience)
7.	Technical drawing skills	The ability to understand and produce technical drawings (by using, e.g. spatial insight)

RESULTS AND DISCUSSION

Data Literacy

According to Pierce (2018) data is a collection of facts, such as numbers, words, sizes, observations or even just descriptions of things. National Science Board (2005) states that data is "any information that can be stored in digital form, including text, numbers, images, video or movies, audio, software, algorithms, equations, animations, models, simulations, etc.". Taken as a whole, the definitions indicate that data is a collection of information that can be stored in electronically (e.g. computer program files) or physically (e.g. printed book).

Data literacy is the ability to read, understand, draw conclusions from, and communicate about raw data (Burke, 2017). According to Mandinach and Gummer (2013) data literacy is “the ability to understand and use data effectively to inform decisions. It is composed of a specific skill set and knowledge base that enables educators to transform data into information and ultimately into actionable knowledge. These skills include knowing how to identify, collect, organise, analyse, summarise and prioritise data. They also include how to develop hypotheses, identify problems, interpret the data, and determine, plan, implement, and monitor courses of action”.

In learning activities, the data is often obtained by the teacher when observing student activities both in the classroom and outside the classroom and when the teacher conducts assessment and evaluation at the end of learning. Data can also be obtained when the teacher develops learning activities such as developing curriculum, teaching materials, teaching methods, and so on. Wayman (2013) argued that teachers can get the data according to the following activities, there are: achievement tests, interim or benchmark assessments, locally-developed periodic assessments, tests, quizzes, disciplinary information, parental information, and teacher observations. On the other view, Mandinach & Gummer (2016) conceived an conceptual framework for data literacy for teachers (DLFT) within three components, content knowledge, pedagogical content knowledge, and data use for teaching (what they termed the knowledge and skills around data use). The conceptual framework is showed in Figure 1.

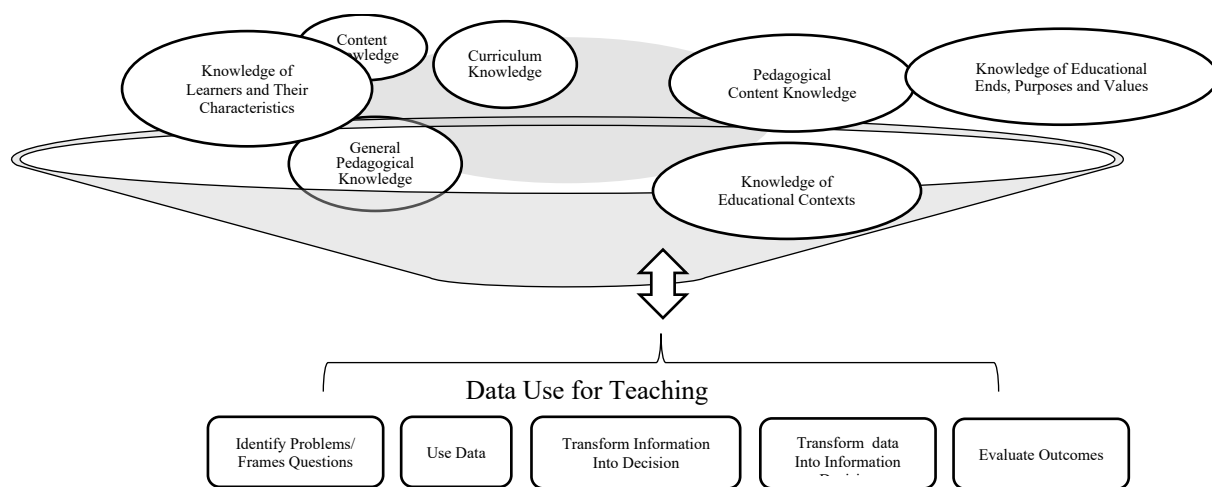


Figure 1. Framework for DLFT Proposed by Mandinach & Gummer (2016)

Furthermore, in the current development of information and communication technology (ICT), data is not only physical, but also evolves into digital data. Digital data is a binary number that processed and produced within a computer system. Currently, the development of digital data has increased into becoming the era of big data. Big data is widely spread on the internet, e-mail, social media and other digital media. The data in question can be text, geometry, images, videos, sounds, and combinations with others (Yang et al., 2017). A teacher needs to have data literacy in sorting, processing, analyzing and interpreting the data.

Moreover, the digital information available on the internet is spreading very quickly. The internet provides an opportunity for everyone to publish freely the quality of information they sent (Siddiq, Scherer & Tondeur, 2015). In dealing with digital information, there are four skills needed by the teacher, namely, accessing, evaluating, sharing and communicating (Ferrari 2013; Siddiq et al., 2015). For example, when accessing and sharing information, a teacher needs to ascertain whether the information obtained is beneficial to him and to others. Therefore, data literacy is a very important skill possessed by teachers in the digital era. In fact, The European Commission lists these areas into the digital competence framework (Digcomp 2.0) as presented in Table 2.

Table 2. Information and data literacy competence areas and competences (European Commission, 2013)

Competence Area	Competences	Description
Information and data literacy	Browsing, searching and filtering data, information and digital content	To articulate information needs, to search for data, information and content in digital environments, to access them and to navigate between them. To create and update personal search strategies.
	Evaluating data, information and digital content	To analyse, compare and critically evaluate the credibility and reliability sources of data, information and digital content. To analyse, interpret and critically evaluate the data, information and digital content.
	Managing data, information and digital content	To organise, store and retrieve data, information and content in digital environments. To organise and process them in a structured environment.

Technical Software Skills

Computer software basically functions as a tool for processing words or processing data. Computer software can be used by teachers both for daily activities and for educational purposes. Furthermore, the development of digital technology, especially software, rapidly vary not only that can be run offline on a computer, but software that can be run online with the help of the internet. The software can be a web-based learning management system that can be used for online learning, web-based office software that can be used for online sharing, social media software that can be used for social networking, microblogging, photo sharing, video sharing, etc. We comprise the types of software based on the skills that teachers need to have in Table 3.

Table 3. Software tools based on the skills teachers should have

Types of Software	Technical Skills
Web-based software	Online courses, online sharring (e.g. file, video), blogging, database management, e-assessment (e.g. using google forms for real-time feedback, moddle for creating learning management system), e-mail, e-portfolio, creating multimedia content (e.g. video tutorial), etc.
Office software	Word processing, spreadsheets, presentation, etc.
Educational software	Educational games, simulations, mathematics problem solving software (e.g. SPSS for statistical analysis), interactive whiteboards, etc.
General Software	Operating system, antivirus, plagiarism checker, reference manager, etc.

Furthermore, the technical software skills are closely related to ICT skills. The ability to use software needs to be accompanied by troubleshooting capabilities (e.g. install, software error, etc). ICT skills are presented in the following figure 2.

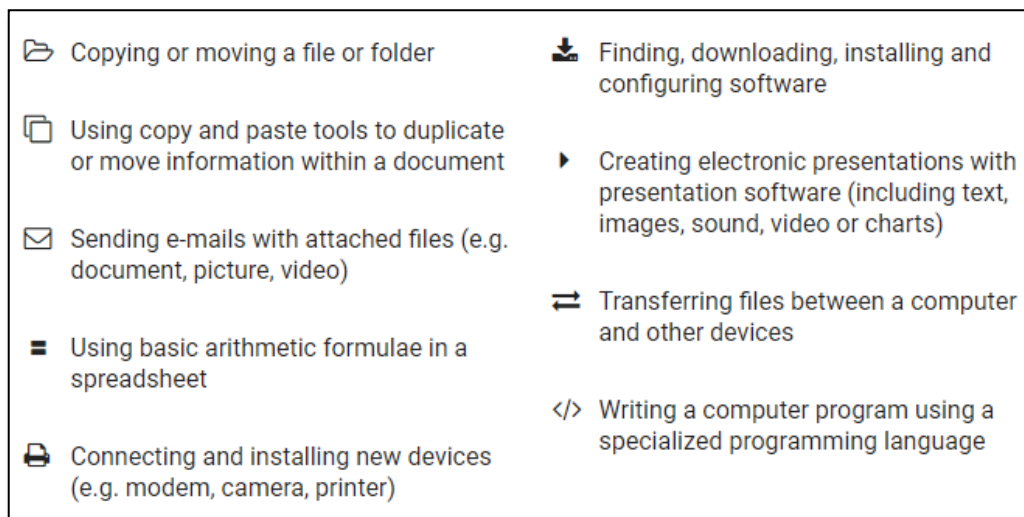


Figure 2. Skills to be measured to assess ict skills adapted from Montoya (2018)

Technical Communication Skills

Communication is an activity of delivering messages from the sender to the recipient. The message delivered can be in the form of verbal and written form. It is the foundation of learning and teaching both in the classroom and outside the classroom, involving interaction between teachers, supervisors, students, parents, and even with the community.

In addition, the use of digital technology today can improve communication and reciprocity between students, teachers, and parents (McKnight et al, 2016). Teachers can communicate through social media such as Facebook, Twitter, YouTube, Instagram, and so on. Teachers can share information as well through Google Docs, Blogging, and create web-based learning media with WebQuest. In communicating using technology, a teacher must have behavioral and responsible norms (Kara, 2018). Some literature called it digital citizenship.

Sense of Error

Another function of a teacher is a verifier. After teachers gained the required literacy, they need to verify the data obtained. In school administration, teachers are often involved in reporting school data to related department to be adapted by policy makers. In evaluating learning activities, a teacher also conducts an error analysis on the results of student learning tests. If teachers fail to have a good grip of this skill, some negative impacts on the education management system of the school will occur.

Additionally, current development of ICT makes it very easy for a teacher to obtain data online through the internet or share data through social media. The available data certainly cannot all be used or even contain errors. In this case, teachers need to trace the source of each data to ensure that it does not contain misleading information.

Sense of Number

In learning and teaching activities a teacher is often faced with numbers, whether arithmetic or algebraically unknown. The number that the teacher often encounters, certainly has meaning. For example, the number found in the student learning outcome, the number of registered new student, the number of a particular subject matter, and so on. Moreover, the ability to interpret numbers is profoundly important when using computer software. Users need to understand what numbers are being inputted and how to interpret the output numbers generated by computer software.

Technical Creativity

Creativity can be considered as a mental process that involves generalizing new ideas or concepts, or the results of new associations between new and given ideas (Leikin et al., 2012). Creativity is the ability to apply various knowledge to solve a problem. There are a lot of teacher activities that involve creativity such as drawing geometry, solving problems in different ways, modeling problems, presenting problem solving with ICTs, and so on. Likewise, creativity is an important aspect of learning and teaching in the 21st century (Craft, 2010; Henriksen et al., 2018).

Technical Drawing Skills

Drawing can be interpreted as making an image using a variety of tools and techniques (Dibujos, 2009; Abass et al., 2014). The development of ICTs currently provides various tools in the form of software that can be used as drawing tools in solving problems. A teacher needs to have the ability to convey ideas in the form of images or vice versa. In addition, the ability to draw is also related to visual-spatial abilities that are part of one's intelligence.

CONCLUSION

The research in the reviewed articles examined the seven categories of techno-mathematical literacy are crucial to teacher education in the digital age. The seven categories are interrelated with each other that it becomes a whole techno-mathematical literacy unit required at the workplace. Teachers suggest that prepare to use technology for teaching, critically evaluate the use and teach children or young people who use digital devices for learning (Starkey, 2020). although being essential for teachers, they are also important for prospective teachers. Thus, the seven TmL categories need to be applied in the teacher education curriculum in higher education to equip students with the skills demanded to face challenges in the workplace.

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