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The Sequential and Conditional Nature of 21st-Century Digital Skills

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The importance of 21st-century digital skills has been well established. However, research often fails to examine how various skills relate to each other. Through a survey of a sample of 1,222 professionals working in the creative industries, we tested, by using path analysis, whether six 21st-century digital skills have a sequential and conditional nature. The sequence of the model starts with information and communication digital skills, followed by collaboration, critical thinking, and creative digital skills. All skills lead to problem-solving digital skills. The results confirm that the analyzed skills build on each other sequentially. To understand what interventions might be successful, the relations among various digital skills should be considered.

Keywords: 21st-century skills, digital skills, 21st-century digital skills, employment, creative industry

In contemporary society, digital skills are an essential component of employability (Ananiadou & Claro, 2009; Autor, Levy, & Murnane, 2003). As global competition becomes increasingly knowledge centric, the requisite digital skills include not only the ability to perform basic practical tasks online, but also a more generic set of skills related to the ability to communicate across cultural and institutional boundaries, to work in remote teams, to create and share knowledge in digital environments (Lanvin & Passman, 2008), and to adapt to changing requirements on the job (Carnevale & Smith, 2013). A plethora of concepts have been introduced to highlight the need to work with technology (Ferrari, 2012)—for example, 21st-century

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skills, digital competence, digital literacy, digital skills, e-skills, Internet skills, and media literacy. The meaning or nature of such concepts is often not clear, causing conceptual debates (Ilomäki, Taalas, & Lakkala, 2012). A recent review systematically evaluated and synthesized conceptualizations and operationalizations used in academic literature (van Laar, van Deursen, van Dijk, & de Haan, 2017). The review resulted in a comprehensive framework of seven 21st-century digital skills that are derived from the multitude of existing concepts: technical, information management, communication, collaboration, creativity, critical thinking, and problem-solving skills.

Traditionally, digital skills are often related to the technical aspects of the medium, and more content-related aspects of digital media—for example, using them to collaborate or solve problems—are neglected (Calvani, Fini, Ranieri, & Picci, 2012; van Deursen, Helsper, & Eynon, 2016; van Deursen & van Dijk, 2011). The current contribution accounts for this by integrating technical and substantive views. The demands on content-related digital skills are becoming increasingly visible in the requirements of 21st-century skills, which are the skills that today's worlds of education and employment need for individuals to function effectively as students, workers, and citizens (Griffin, Care, & McGaw, 2012). The term generally refers to a wider range of skills, whereas technical skills are often described as a separate subset within these frameworks (Siddiq, Hatlevik, Olsen, Throndsen, & Scherer, 2016). The essence of what we call 21st-century digital skills is that they define what employees can do with information and communication technology (ICT) to support the broader spectrum of 21st-century skills and in turn take full advantage of ICTs.

In most conceptualizations of digital skills and of 21st-century skills, the relevant skills are considered and analyzed separately, as if they are independent of each other. Yet, studies focusing on Internet skills have revealed that there is a sequential and conditional nature present among skills (van Deursen, Helsper, Eynon, & van Dijk, 2017; van Deursen & van Dijk, 2016). Lacking the more technical skills, for example, means that one will not even have the opportunity to perform the other skills. This study aims to extend existing empirical knowledge regarding 21st-century digital skills by analyzing their sequential nature. Because a large number of policy initiatives are being developed that are aimed at a skilled workforce, understanding how different types of skills relate to each other is important for designing interventions. The following research question is addressed:

RQ: *What is the relation among the 21st-century digital skills pertaining to information, communication, collaboration, critical thinking, creativity, and problem solving?*

To answer this question, the current study is conducted in the creative industries (CI). The CI represent the industrial components of the economy in which creativity is an input, and content or intellectual property is the output (Potts & Cunningham, 2008). The creative sector represents a knowledge-intensive industry characterized by rapid technological changes (Musterd, Bontje, Chapain, Kovacs, & Murie, 2007); it is a sector where new and complex knowledge is continuously being created and demanded (Kamprath & Mietzner, 2015).

Theoretical Framework

To obtain a comprehensive picture of how skills interrelate, this study builds on a previous systematic literature review conducted to synthesize the relevant academic literature addressing 21st-century and digital skills concepts (van Laar et al., 2017). Existing frameworks were used to identify the most important 21st-century digital skills and to provide conceptual definitions for them aimed at the knowledge worker. Based on this review, the following 21st-century digital skills were operationalized: information management and evaluation, communication expressiveness, contact building, networking, and content sharing, collaboration, critical thinking, creativity, and problem solving (van Laar, van Deursen, van Dijk, & de Haan, 2018). It is important to note that critical thinking and creativity are often considered to be individual attributes that one either has or does not have. However, these attributes are skills that can be developed through practice (Amabile & Pillemer, 2012). For example, aspects of critical thinking (e.g., considering information from different viewpoints) and creativity (e.g., generating novel and useful ideas) can be learned through practice. This study focuses on the aspects of skills that can be improved by experience, learning, and training. In what follows, we describe the expected relations among 21st-century digital skills. Based on the literature, we build a conceptual model with the highest level problem-solving skills.

The growing use and spread of ICTs make it important for individuals to develop problem-solving digital skills. As routine tasks are increasingly automated, the demand for jobs that require employees to solve complex problems is on the rise. Employees need the skills to formulate the problem, recognize the context within which the problem occurs, and specify the demands that any solution needs to be successful. Problem solving is considered the highest form of learning (Gagné, 1985). It involves both the acquisition and the application of new knowledge in situations that must be actively explored to find and apply a solution (Mainert, Niepel, Murphy, & Greiff, 2018). Knowledge can be derived from diverse sources accessible online. Web 2.0 engages people in collective learning; they help, support, and encourage each other as they work on problems and seek new forms of knowledge.

When employees exhibit high creative digital skills at work, they are more likely to generate novel and useful ideas for new products, services, and processes by using the Internet. The digital environment supports employees' creativity in knowledge gathering, integration, and generation (Karakaya & Demirkan, 2015). Digital technologies allow people to express themselves in new ways, to make original and valued contributions, and to broaden opportunities for realizing the products of their imaginations (Loveless, 2003). A person with high levels of creative digital skills knows the culture and norms of the online world and where to post and upload creative content within the boundaries of acceptable social behavior (Park, 2012). Creative thinking is an important component of Web-based problem solving (Kuo & Hwang, 2014). It involves the generation of a variety of ideas, which is a strong predictor of innovative problem solving (Dumas, Schmidt, & Alexander, 2016). We hypothesize that:

H1: Creative digital skills contribute positively to problem-solving digital skills.

Critical thinking digital skills involve making judgments about the quality of information and communication presented online (Manalo, Kusumi, Koyasu, Michita, & Tanaka, 2013). These skills help

individuals to consider content from different points of view (Wechsler et al., 2018) and to make informed judgments and choices about information and communication, enabling successful performance in a given task. In an age of disinformation and fake news, a person must think critically to determine whether information or communication is trustworthy (Keshavarz, 2014). Critical thinking is essential if one is to differentiate accurate information and communication from manipulation. Furthermore, in critical thinking, evidence and arguments need to be evaluated independently of prior beliefs and opinions that one may hold (West, Toplak, & Stanovich, 2008). Critical thinking plays a role in the acquisition of knowledge, as it is only through engaging interpretations and inferences that new knowledge is created and internalized (Voskoglou & Buckley, 2012). Creativity without critical thought reduces to mere novelty (Paul & Elder, 2006). An accurate judgment of the creativity of ideas is an important component underlying creative performance (Benedek et al., 2016; Eggers, Lovelace, & Kraft, 2017). Critical thinking assumes that individuals have the skills to analyze evidence and test the "logic of ideas, proposals, and courses of action" (Rousseau, 2012, p. 3), thereby increasing creativity as measured through unique product designs created (Eggers et al., 2017). Furthermore, critical thinking is an important component of Web-based problem solving (Kuo & Hwang, 2014); it is expressed through reflection and open-minded thinking about alternatives, which is considered key to facilitating problem solving (Hong & Choi, 2015; Hyytinen, Holma, Toom, Shavelson, & Lindblom-Ylänne, 2014). Educating about critical thinking has a positive effect on problem-solving skills (Kanbay & Okanlı, 2017). Whitten and Brahmasrene (2011) describe critical thinking as the "cognitive engine which drives problem-solving and decision-making" (p. 1). Through consideration of alternatives and exploration of contradictions and probabilities (Moeller, Cutler, Fiedler, & Weier, 2013), critical thinking skills help individuals to make the right decision (Paul & Elder, 2004). We hypothesize:

H2: Critical thinking digital skills contribute positively to creative digital skills.

H3: Critical thinking digital skills contribute positively to problem-solving digital skills.

The term *collaboration digital skills* refers to the ability to operate cooperatively online in pursuit of a common objective (Green, Ashton, & Felstead, 2001). Work is increasingly performed by teams of people with complementary roles and expertise. Successful collaboration is dependent on the ability to divide a task into pieces based on the strengths of the individuals while also ensuring that each team member has a clear sense of the entire project (Bronstein, 2003; Dede, 2010). Because of the importance of knowledge in today's competitive world, as well as the growth of virtual communities and geographically dispersed teams, an understanding of how to enhance employees' online knowledge-sharing behavior has become critical, especially given that higher levels of interaction are necessary to accomplish interdependent work tasks. Collaboration processes—managing interdependencies across time to achieve a common goal—are increasingly supported by ICT, which provides the flexibility to work collaboratively beyond the restrictions of time and place. We expect collaboration digital skills to contribute to better critical thinking, creative, and problem-solving digital skills. Teamwork activities can encourage critical thinking development (Magrabi, Pasha, & Pasha, 2018). Interactions involving conflicting viewpoints promote more discussion, and individuals actively engage in the application of knowledge (Jeong, 2003). Research revealed that to stimulate critical thinking, it is important to engage in collaborative processes such as reciprocal dialogues (Petrucco & Ferranti, 2017). Moreover, shared

knowledge is a useful resource for working on creative ideas and solutions (Binnewies, Ohly, & Sonnentag, 2007). Creativity is often a result of a social process (Perry-Smith & Shalley, 2003; Sawyer & DeZutter, 2009) in which employees share knowledge by communicating task-related ideas, information, and know-how required by their colleagues (Wang & Noe, 2010). In relation to problem solving, when the complexity of a problem increases, it becomes necessary to work collaboratively. Each team member possesses unique expert information that must be integrated to achieve a viable solution (Rentsch, Mello, & Delise, 2010). Collaboration skills may help the individual and the group realize their potential (Dong, Bartol, Zhang, & Li, 2017; Lin, Mills, & Ifenthaler, 2016). We hypothesize:

H4: Collaboration digital skills contribute positively to critical thinking digital skills.

H5: Collaboration digital skills contribute positively to creative digital skills.

H6: Collaboration digital skills contribute positively to problem-solving digital skills.

Communication digital skills pertain to effectively expressing and sharing online content by considering the audience and medium. These skills involve expressiveness, defined as the ability to express feelings and reactions clearly and openly in a digital environment. Additionally, these skills involve building and maintaining contacts, which are preconditions for using network contacts who possess the resources necessary to facilitate resource mobilization (Wolff & Moser, 2010). Networking refers to individuals' ability to make online connections and contacts for instrumental or expressive returns (Lee & Chen, 2017). Finally, communication digital skills concern content sharing, or the ability to participate in and make use of online platforms to share information (Sigala & Chalkiti, 2015). Platforms such as social networking sites, blogs, and wikis are increasingly used to share digital content. Chiu, Hsu, and Wang (2006) found that social interaction and socializing were related to online content-sharing behaviors. The rise of social network sites is intensifying the use of participatory online activities through communication among users who maintain existing social relations and make new social connections online (boyd & Ellison, 2007). Individuals are able to express themselves, establish relationships, and interact with others at any distance of time and space (Yu, Tian, Vogel, & Kwok, 2010). This study focuses on the following components of communication digital skills: expressiveness, contact building, social networking, and content sharing. Because contact building, social networking, and content sharing involve expression, expression is expected to contribute to the level of these components. Furthermore, it is expected that one first needs to establish online contacts before starting to network and in turn share content. We hypothesize:

H7: Communication expressiveness has a positive influence on (a) building, (b) networking, and (c) sharing. Communication building has a positive influence on (d) networking and (e) sharing. Communication networking has a positive influence on (f) sharing.

Online communication (e.g., e-mail, discussion forums, and social media) has become an important way for individuals to interact (Li, Shi, & Dang, 2014). Accordingly, extensive network contacts can increase team members' understanding of others' skills and knowledge and can help individuals find relevant experts when specific knowledge is needed. Furthermore, the expression of critical thinking relies

on communicative competences, such as the ability to debate, express informed opinions, and evaluate and respect the opinion of others (Volman & Ten Dam, 2015). Similar arguments account for creativity. Prior research has highlighted that employees who engage in higher levels of social media exploitation and who join various social networks and media achieve higher levels of creativity (Sigala & Chalkiti, 2015). To engage in creative digital activities, a person needs the skills to understand issues such as media language and how to reach audiences (Park, 2012). Prior studies have revealed that social Internet skills directly relate to creative Internet skills (van Deursen et al., 2017). Finally, previous research has revealed that problem solving requires the effective use of communication skills (Erozkan, 2013). We hypothesize that:

H8: Communication digital skills (expressiveness, building, networking, and sharing) contribute positively to collaboration digital skills.

H9: Communication digital skills (expressiveness, building, networking, and sharing) contribute positively to critical thinking digital skills.

H10: Communication digital skills (expressiveness, building, networking, and sharing) contribute positively to creative digital skills.

H11: Communication digital skills (expressiveness, building, networking, and sharing) contribute positively to problem-solving digital skills.

Information digital skills are defined as the ability to find, evaluate, and effectively use information online (Kiliç-Çakmak, 2010; Kurbanoglu, Akkoyunlu, & Umay, 2006). Given the rapid increase in new ICTs and the multiplication of information sources, the importance of information digital skills is increasing (Yilmaz, 2016). It is possible to access numerous resources on any subject online. However, one has to decide whether the information accessed is reliable and worthwhile enough to be useful. Especially in an information-dense society where knowledge changes and becomes outdated rapidly (Ross, Perkins, & Bodey, 2016), employees will need skills to manage the quantity and quality of information. Information skills are considered multidimensional, and key components include management and evaluation. Information management skills are needed to organize information effectively for easy retrieval. Because the Internet offers opportunities for everyone to publish regardless of the quality of the information dispatched, it is essential for individuals to first develop the skills required to manage digital information (Siddiq, Scherer, & Tondeur, 2016). Information evaluation skills are needed to make informed decisions about the quantity and quality of the received information (e.g., in terms of reliability, relevance, and accuracy). We hypothesize:

H12: Information management has a positive influence on information evaluation digital skills.

Once information has been found and organized, a person can transform and develop that information in a variety of ways to communicate it more effectively to others and to develop his or her own ideas or interpretations on the basis of the task to be solved (Ananiadou & Claro, 2009). Additionally, the ability to analyze, interpret, and evaluate information online is positively related to communication

networking skills (Lee & Chen, 2017). Similarly, a recent study revealed that information-navigation skills directly relate to having online social skills (van Deursen et al., 2017). We also expect a direct contribution to collaboration skills, because prior research has revealed that information skills predict collaboration on Facebook (Khan, Wohn, & Ellison, 2014). Moreover, in line with previous research, it is expected that critical thinking requires information retrieval and evaluation first (Koltay, 2011; Weiner, 2011). Finally, Web-based problem solving is a high-order thinking process that also consists of searching for information on the Internet (Kuo & Hwang, 2014). To solve challenging tasks in problem situations, individuals have to perform cognitive activities, such as activating existing knowledge and organizing new information (Ifenthaler, 2012). We hypothesize:

H13: Information digital skills (evaluation and management) contribute positively to communication digital skills (expressiveness, building, networking, and sharing).

H14: Information digital skills (evaluation and management) contribute positively to collaboration digital skills.

H15: Information digital skills (evaluation and management) contribute positively to critical thinking digital skills.

H16: Information digital skills (evaluation and management) contribute positively to problem-solving digital skills.

According to the discussed theoretical considerations, we propose the conceptual model in Figure 1.

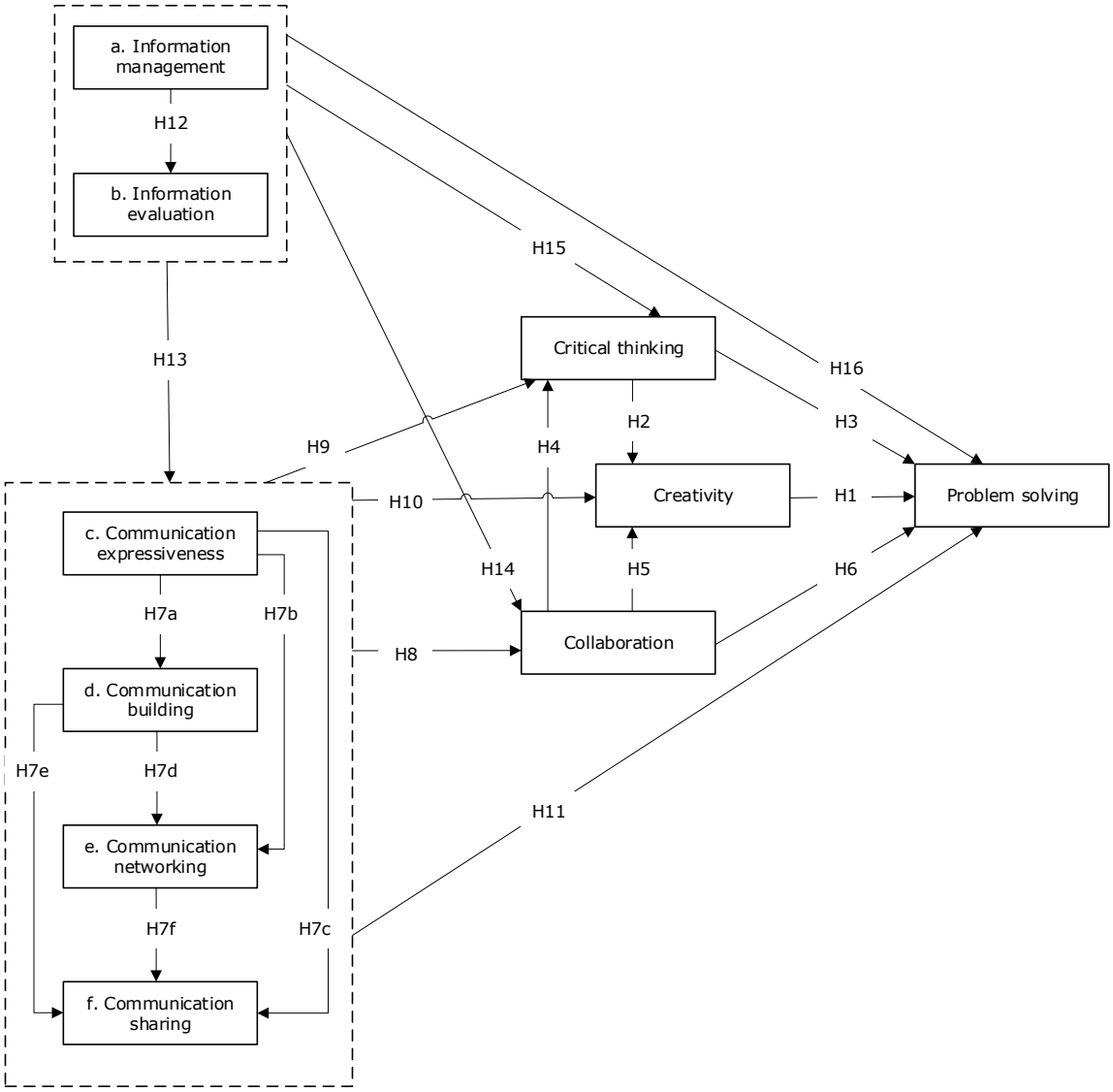

Figure 1. Conceptual model and proposed hypotheses.

Method

Sample and Procedure

An online survey was conducted to test the relations among 21st-century digital skills. The study was conducted among professionals working within the CI. The data were collected from October to December 2017. To obtain a sample of CI in the Netherlands, we used two online panels that used screening questions to ensure that respondents were working within the CI. Members received a small incentive for their participation. Additionally, we approached respondents by e-mail. The potential respondents were screened using LinkedIn or their employer's website. Respondents received an incentive of €10 if they completed the online survey. Participants were ensured that their results would not be reported to their workplaces. The final sample included 1,222 professionals who were directly involved in creative work processes that spanned initial analysis of the problem to the introduction of a product, process, or service in the market. The job functions ranged from strategists, business developers, and designers to software engineers and marketers on all levels. See Table 1.

Table 1. Sample Characteristics.

		N	%
Gender			
	Male	646	52.9
	Female	576	47.1
Age			
	18–30	373	30.6
	31–45	467	38.3
	46–60	303	24.8
	60+	77	6.3
	Missing	2	0.2
Education			
	Medium	294	24.1
	High	928	75.9
Branch organization			
	Advertising/marketing	136	11.1
	Graphic design	115	9.4
	Performing art	106	8.7
	New media/software	105	8.6
	Radio/television	97	7.9
	Visual art/photography	89	7.3
	Architecture	84	6.9
	Publishing/media	72	5.9
	Journalism	72	5.9
	Industrial design	64	5.2
	Fashion/textile design	61	5.0

Museum	61	5.0
Gaming	58	4.7
Film	53	4.3
Books/magazines	49	4.0

Measures

Ideally, the measurement of 21st-century digital skills should involve the actual use of Internet applications (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014). Performance tests have proved to be a very suitable way to obtain a realistic view of people's digital skills, but their cost and the time needed to conduct them are strong limitations for large-scale data gathering. Therefore, self-assessment has been widely reported as a proxy measure of actual digital skill levels (Siddiq, Hatlevik, Olsen, Throndsen, & Scherer, 2016). However, self-assessments have significant validity problems because people have difficulty judging their own skills. Evidence shows that young men especially overrate their performance (Hargittai & Shafer, 2006). Other measures derive the level of digital skills from the intensity of engagement in a variety of skill-related actions. They are less subject to overrating and show higher correlations with actual performance tests as compared with the use of agreement scales (van Deursen, van Dijk, & Peters, 2012).

To measure 21st-century digital skills, we used van Laar and colleagues' (2018) instrument. Frequency scales were used to measure how often respondents perform certain skill-related actions at work, and that information functioned as a behavioral indicator of skills. Respondents were asked to answer the items using a 5-point Likert scale ranging from 1 (*never*) to 5 (*[almost] always*). Cronbach's alpha exceeded the required threshold of 0.7, which implies high internal consistency of the scales. Table 2 displays the measures used, including the means, standard deviations, and reliability scores.

Table 2. Means, Standard Deviations, and Reliability of the Measures.

	M	*SD*
The next statements are about processing information for work-related purposes. At work, how often…		
Information management (α = .76)	4.06	0.79
do you save useful digital files directly to the right folder?	4.21	0.82
are you consistent in the naming of digital files?	4.00	0.95
do you organize digital files via a hierarchical folder structure?	3.98	1.07
The next statements are about searching information for work-related purposes. At work, how often…		
Information evaluation (α = .71)	3.67	0.72
do you check the reliability of a website?	3.56	0.98
do you check the information found on a different website?	3.50	0.89
do you check whether the information found is up to date?	3.95	0.82
The next statements are about profiling yourself online for work-related purposes. At work, how often…		

Communication expressiveness (α = .79)	3.83	0.60
do you get what you want from interactions on the Internet?	3.71	0.73
are you effective in accomplishing what you want via the Internet?	3.87	0.72
do you know how to use the Internet to express ideas clearly?	3.90	0.72
Communication building (α = .84)	2.83	0.90
do new collaborations emerge by approaching online contacts?	2.81	0.99
do you establish online contacts to collaborate with?	3.02	1.04
do you find experts on the Internet to start a project with?	2.65	1.07
Communication networking (α = .92)	3.04	0.81
do you spend time and effort networking online with people from your field?	3.04	1.00
do you use your online network to benefit from it?	3.09	1.00
do you use your online network to generate business?	2.92	1.08
do you build online relationships with people from your field?	3.27	0.96
does the Internet help you approach new professional contacts?	3.29	0.90
do you use your online network to increase brand awareness?	3.16	1.09
do you start a conversation with other professionals via the Internet?	2.81	1.04
do you use your online network to achieve policy goals?	2.72	1.01
Communication sharing (α = .77)	2.64	0.89
do you post new messages on the Internet?	3.11	1.05
do you post a blog/article on the Internet?	2.36	1.12
do you share information on the Internet to start a discussion?	2.46	1.04
The next statements are about sharing information for work-related purposes. At work, how often…		
Collaboration (α = .93)	3.31	0.79
do you share important information with your team via the Internet?	3.47	1.05
do you use the Internet to share information that supports the work of others?	3.38	1.00
do you use the Internet to share resources that help the team perform tasks?	3.27	1.06
do you use the Internet to provide each other with information that allows work to progress?	3.52	1.00
does the Internet help you get support from coworkers?	3.19	0.98
do you communicate via the Internet with coworkers from other disciplines?	3.32	1.03
do you share work-related knowledge with each other via the Internet?	3.35	0.94
do you use the Internet to give feedback to coworkers?	3.09	1.08
does the Internet help you use other professionals' expertise?	3.24	0.85
The next statements are about having online discussions (e.g., e-mail, Skype, online forums) for work-related purposes. At work, how often…		
Critical thinking (α = .94)	3.39	0.70
do you give substantiated arguments or reasoning?	3.57	0.93

do you give proof or examples of arguments you present?	3.34	0.91
do you give a justification for your point of view?	3.45	0.91
are you able to put the discussion into a new perspective?	3.25	0.86
do you ask questions to understand other people's viewpoints?	3.49	0.96
do you consider various arguments to formulate your own point of view?	3.54	0.88
do you connect viewpoints to give a new turn to the discussion?	3.22	0.91
do you suggest new related points?	3.15	0.89
do you filter the most important points from discussions?	3.59	0.91
do you generate new input from a discussion?	3.26	0.85
are you open to ideas that challenge some of your beliefs?	3.50	0.86
do you use the Internet to justify your choices?	3.25	0.89
At work, how often…		
Creativity (α = .89)	3.30	0.73
do you give a creative turn to existing processes using the Internet?	3.16	0.89
do you use the Internet to generate innovative ideas for your field?	3.34	0.90
do you show originality in your work using the Internet?	3.25	0.94
do you use the Internet to execute your tasks creatively?	3.38	0.87
do you follow trends on the Internet to generate original ideas?	3.46	0.93
do you use the Internet to evaluate the usability of your ideas?	3.21	0.93
The next statements are about problems at work that you want to solve by using the Internet. At work, how often…		
Problem solving (α = .92)	3.52	0.61
does the Internet help you find the best way to solve the problem?	3.56	0.75
do you solve the problem using the Internet?	3.47	0.81
do you come up with solutions to the problem via the Internet?	3.58	0.78
does the Internet help you find ways to solve problems?	3.72	0.74
are you confronted with a problem that you are sure you can solve using the Internet?	3.38	0.82
do you make a decision using the Internet that makes you feel happy afterward?	3.56	0.75
do you find the solution via the Internet even though initially no solution is immediately apparent?	3.32	0.77
does the actual outcome you achieved via the Internet match what you expected?	3.55	0.71

Note. The items were asked in Dutch on a 5-point Likert scale: 1 = *never*, 2 = *rarely*, 3 = *sometimes*, 4 = *often*, 5 = *(almost) always*.

Data Analysis

To test our hypotheses, we applied path modeling using Amos 23.0. Because we used validated scales that consisted of a large number of items, we submitted composite scales to the analysis rather than the individual items (Bandalos & Finney, 2001). To obtain a comprehensive model fit, we included the indices suggested by Hair, Black, Babin, Anderson, and Tatham (2006): the χ^2 statistic, the ratio of χ^2 to its degree of freedom (χ^2/df), the standardized root mean residual (SRMR), the Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA).

Results

Structural and Path Model

The conceptual model as presented in Figure 1 resulted in a slightly overfit model, meaning that the model has more parameters than can be justified by the data, reducing generalizability. To improve model fit, we removed 10 insignificant paths. The resulting model provided a good fit: $\chi^2(12) = 16.71$; $\chi^2/df = 1.39$; SRMR = .01; TLI = .99; RMSEA = .02, 90% CI [.00, .09]. Table 3 provides the correlations among the skills.

Table 3. Correlation Matrix.

	1	2	3	4	5	6	7	8	9	10
1. Evaluation	-	.15**	.25**	.22**	.29**	.19**	.20**	.29**	.22**	.18**
2. Management	-	-	.18**	-.02	.02	.02	.12**	.10**	.05	.14**
3. Expressiveness	-	-	-	.27**	.24**	.24**	.26**	.28**	.35**	.40**
4. Sharing	-	-	-	-	.54**	.50**	.31**	.30**	.40**	.17**
5. Building	-	-	-	-	-	.66**	.36**	.34**	.42**	.20**
6. Networking	-	-	-	-	-	-	.43**	.33**	.51**	.21**
7. Collaboration	-	-	-	-	-	-	-	.43**	.38**	.28**
8. Critical thinking	-	-	-	-	-	-	-	-	.36**	.25**
9. Creativity	-	-	-	-	-	-	-	-	-	.42**
10. Problem solving	-	-	-	-	-	-	-	-	-	-

Note. Significant at $p < .01$.

Figure 2 provides the path models with coefficients and variances explained.

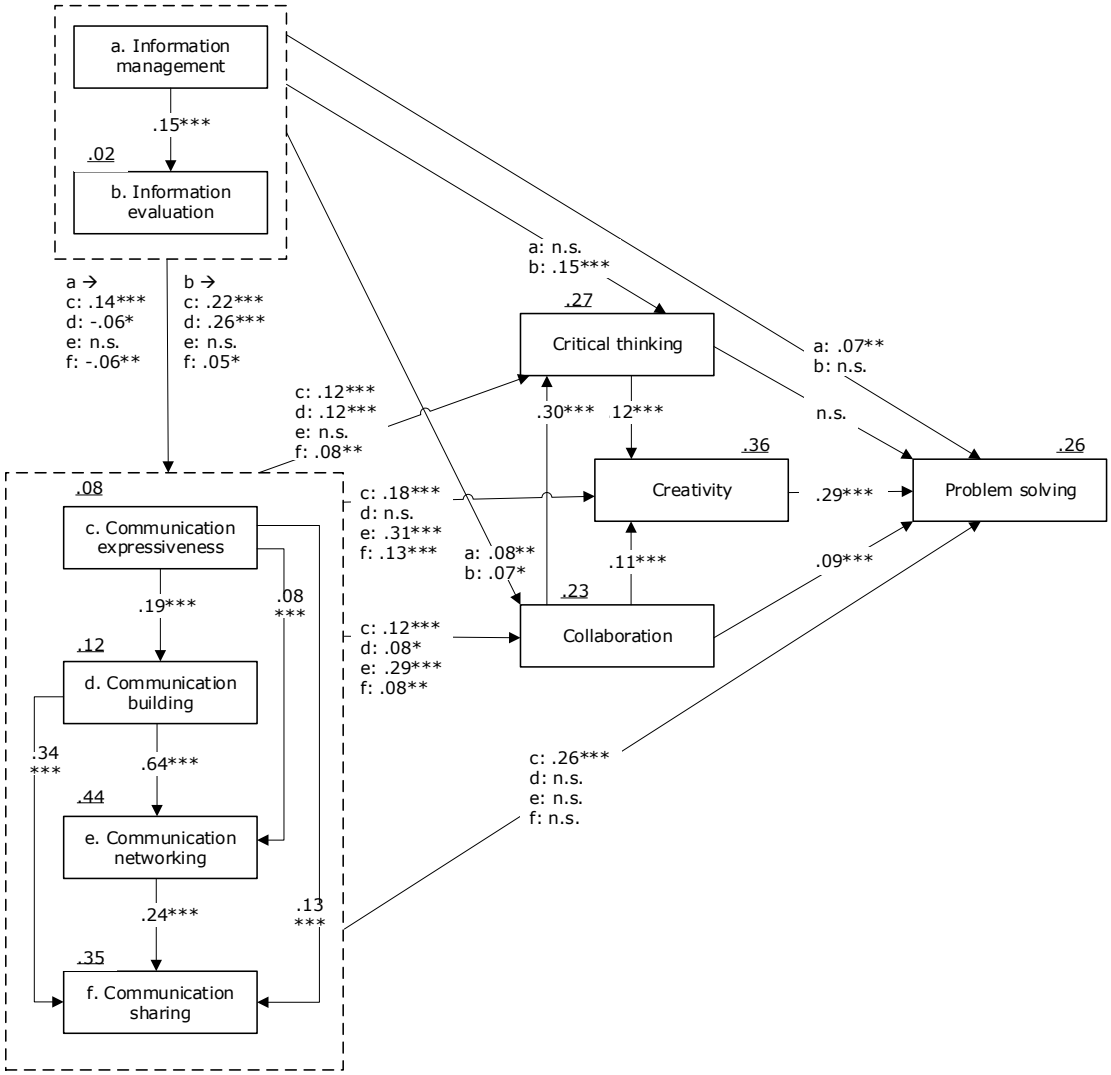

Figure 2. Results for the research model with path coefficients.

*Note: *p < .05; **p < .01; ***p < .001 level. Squared multiple correlations are underlined.*

Overview of the Hypotheses

The standardized path coefficients in Figure 2 reveal several significant direct and indirect paths among the 21st-century digital skills. Table 4 summarizes the hypotheses. The first hypothesis is confirmed; creative digital skills contribute positively to problem-solving digital skills. Critical thinking digital skills contribute positively to creative digital skills, offering support for H2. Because critical thinking digital skills only contribute indirectly to problem-solving digital skills, H3 is partially supported.

Table 4. Standardized Direct, Indirect, and Total Effects.

Hypotheses	Direct β	Indirect β	Total β	Validation
H1. Creativity → Problem solving	.29	-	.29	Supported
H2. Critical thinking → Creativity	.12	-	.12	Supported
H3. Critical thinking → Problem solving	-	.03	.03	Partly
H4. Collaboration → Critical thinking	.30	-	.30	Supported
H5. Collaboration → Creativity	.11	.04	.15	Supported
H6. Collaboration → Problem solving	.09	.04	.13	Supported
H7a. Expressiveness → Building	.19	-	.19	Supported
H7b. Expressiveness → Networking	.08	.12	.20	Supported
H7c. Expressiveness → Sharing	.13	.11	.24	Supported
H7d. Building → Networking	.64	-	.64	Supported
H7e. Building → Sharing	.34	.16	.50	Supported
H7f. Networking → Sharing	.24	-	.24	Supported
H8. Expressiveness → Collaboration	.12	.09	.21	Supported
H8. Building → Collaboration	.08	.23	.31	Supported
H8. Networking → Collaboration	.29	.02	.31	Supported
H8. Sharing → Collaboration	.08	-	.08	Supported
H9. Expressiveness → Critical thinking	.12	.10	.22	Supported
H9. Building → Critical thinking	.12	.13	.25	Supported
H9. Networking → Critical thinking	-	.11	.11	Partly
H9. Sharing → Critical thinking	.08	.02	.10	Supported
H10. Expressiveness → Creativity	.18	.14	.32	Supported
H10. Building → Creativity	-	.33	.33	Partly
H10. Networking → Creativity	.31	.08	.39	Supported
H10. Sharing → Creativity	.13	.02	.15	Supported
H11. Expressiveness → Problem solving	.26	.11	.37	Supported
H11. Building → Problem solving	-	.12	.12	Partly
H11. Networking → Problem solving	-	.14	.14	Partly
H11. Sharing → Problem solving	-	.05	.05	Partly
H12. Management → Evaluation	.15	-	.15	Supported
H13. Management → Expressiveness	.14	.03	.17	Supported
H13. Management → Building	−.06	.07	.01	Partly
H13. Management → Networking	-	.02	.02	Partly
H13. Management → Sharing	−.06	.04	−.02	Rejected
H13. Evaluation → Expressiveness	.22	-	.22	Supported
H13. Evaluation → Building	.26	.04	.30	Supported

H13. Evaluation → Networking	-	.21	.21	Partly
H13. Evaluation → Sharing	.05	.18	.23	Supported
H14. Management → Collaboration	.08	.04	.12	Supported
H14. Evaluation → Collaboration	.07	.13	.20	Supported
H15. Management → Critical thinking	-	.08	.08	Partly
H15. Evaluation → Critical thinking	.15	.14	.29	Supported
H16. Management → Problem solving	.07	.07	.14	Supported
H16. Evaluation → Problem solving	-	.13	.13	Partly

Collaboration digital skills contribute positively to critical thinking digital skills, creative digital skills, and problem-solving digital skills, offering support for H4, H5, and H6.

H7a–f are also supported, confirming the conditional nature among the digital communication components. Expressiveness has a positive influence on building, networking, and sharing. Building has a positive influence on networking and sharing. Finally, networking positively influences sharing.

All communication digital skills contribute positively to collaboration digital skills, confirming H8. H9, concerning the relation between the digital communication components and critical thinking digital skills, is partly supported. Communication expressiveness, building, and sharing have a positive direct effect on critical thinking, but networking only has a positive indirect effect on critical thinking. H10, concerning the relation between the digital communication components and creative digital skills, is also partly supported. Communication expressiveness, networking, and sharing have a positive direct effect on creativity, but building only has an indirect positive effect on creativity. Finally, communication expressiveness has a positive direct effect on problem-solving digital skills, but building, networking, and sharing only have a positive indirect effect, offering partial support for H11.

H12, concerning the relation among the digital information components, is supported: Information management has a positive influence on information evaluation.

H13 involves the positive relation among the digital information components and all the digital communication components. Information management only has a direct and positive effect on expressiveness. The direct effect of information management on building and sharing is negative. However, we did find a positive indirect effect of information management on building and sharing. Furthermore, we found a positive indirect effect of information management on networking. Information evaluation has a direct and positive effect on expressiveness, building, and networking. However, we only found a positive indirect effect of information evaluation on networking; H13 is therefore partly supported. Because both information digital skills contribute positively to collaboration digital skills, H14 is confirmed. Concerning H15, information management only has a positive indirect effect, and information evaluation has a positive direct effect on critical thinking. Therefore, H15 is partly supported. Finally, information management has a positive direct effect on problem-solving digital skills, and information evaluation has a positive indirect effect, offering partial support for H16.

Discussion

Main Findings

In today's rapidly changing knowledge economy, 21st-century digital skills are decisive for an organization's competitiveness and innovation capacity. Given the rapid rate of change and the influence of technology, employees must develop 21st-century digital skills (information, communication, collaboration, critical thinking, creativity, and problem solving) to cope and thrive. The development of these skills, however, requires a thorough understanding of how these skills interrelate; we cannot expect that all these skills will be developed independently. Yet, existing conceptualizations of both digital skills and 21st-century skills often consider each skill separately. Although this might provide useful insights into the level of a specific skill, it remains difficult to actually design interventions without understanding what other skills are needed to perform well on a specific skill. For example, directly focusing on the improvement of collaboration skills will be less effective compared with programs that first focus on repairing insufficient information and communication skills, which are required for performing well on collaboration digital skills. Thus, the purpose of this study was to reveal how the most important 21st-century digital skills interrelate. The results of this study emphasize the importance of this idea; the 21st-century digital skills under investigation showed gradients of difficulty and also have a sequential and conditional nature. In other words, the skills build on each other sequentially; a person who lacks one type of skill is also likely to lack another. Our empirically tested model begins with being able to manage and evaluate digital information, and it ends with being able to solve problems using the Internet. The intermediaries are collaboration, critical thinking, and creative digital skills.

An important finding is that, except for critical thinking digital skills, the results confirm that all skills lead directly to problem-solving digital skills. The specific requirements of information-intensive knowledge societies are becoming increasingly strategic (Lanvin & Kralik, 2009). Problem solving has always been a major human asset, but with new global technologies interacting with complex, opaque, and dynamic problems, it is increasingly important for producing competitive products (Anderson, 2008; Neubert, Mainert, Kretzschmar, & Greiff, 2015). Furthermore, it will not be possible to effectively solve complex problems without the control of information, communication, collaboration, and creative digital skills. The absence of these skills means that one will not even reach the point of performing problem-solving digital skills. This is important, because this strong dependence has major implications concerning the development and justification of interventions targeting skill improvement. Insights gained from this study can be used to justify the order in which the proposed 21st-century digital skills are developed. In the work context, for example, it is reasonable to first design and create effective instruction to develop employees' information digital skills. Once the level of information digital skills is sufficient, it is useful to focus on the development of communication digital skills and so on.

Limitations and Future Research Directions

The model as presented in Figure 2 provides a good fit solution of the sample data: professionals working in the CI. In light of the conceptual and empirical evidence, the presented model provides a realistic

overview of the sequence of the skills under investigation. Yet, future research should further build upon the idea that skills interrelate. Other models might be possible, as for example we did not account for two-way interactions between skills.

Future research could also extend this study by incorporating other skills. For example, entrepreneurship is recognized as an increasingly important 21st-century skill (Voogt & Roblin, 2012). Moreover, the ability to clearly define information needs is a key operational component of information digital skills (e.g., Çoklar, Yaman, & Yurdakul, 2017; Katz, 2007). However, the instrument that we used did not cover this component. Although these are just examples, they indicate that there might be as yet unrecognized skills and key operational components of skills that could extend our understanding of 21st-century digital skills. The adopted framework of 21st-century digital skills departs from the multitude of existing concepts (e.g., 21st-century skills, digital competence, digital literacy, and digital skills) aimed at the skills of knowledge workers, but the digital skills needed for work in the 21st century are continuously evolving (Redecker & Johannessen, 2013). Although we aimed to test digital skills, previous research has shown that participants find it difficult to separate the offline from the online when evaluating their own skill levels (van Deursen, Helsper, & Eynon, 2014). However, engaging in certain skills-related activities online may not automatically lead to achieving the related skills offline. Future research could test to what extent offline 21st-century skills show comparable results.

Although the survey instrument used in this study avoids common response formats such as self-evaluation (*how good are you at . . .?*) or agreement (*how much do you agree?*) scales, the measures are based on self-reports. Interpretations of skills depend not only on perspective and context but also on the people to whom respondents compare themselves (Talja, 2005). To account for this problem of validity and cover actual behavior, we used a survey instrument that measures the frequency of various skill-related activities instead of the more indirect measure of self-evaluation. van Deursen et al. (2012) found that some of the frequency items proposed serve as the best proxies for measuring Internet skills in surveys.

Finally, considering the general nature of the skill components used in this study, there is no reason to think that the results of this study would apply only to CI in the Netherlands. CI are characterized by considerable variation within the workforce (Chen, Chang, & Lo, 2015), and we chose this sector because of its knowledge-intensive work activities and the representation of a wide range of industries. Yet, the identified interrelation among the different skills should also be tested in different contexts. The relative importance of some skills might differ among domains, and such differences might also affect the sequential and conditional nature of 21st-century digital skills.

Conclusion

To conclude, 21st-century digital skills show gradients of difficulty and have a sequential and conditional nature. In other words, these skills build on each other sequentially. This suggests that improving specific skills alone will not be enough. The conclusion that the broad range of 21st-century digital skills depend on each other has received minimal attention thus far. For a better understanding of how skill divides emerge, or what type of skill improvement interventions might be most successful, it is important to consider

the relations among various digital skills. These increasingly determine people's positions in the labor market and social life in our contemporary knowledge society.

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