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Teaching in a Digital Environment (TIDE): Defining and measuring teachers' capacity to develop students' digital information and communication skills

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ABSTRACT

The study presented in this paper consisted in defining a Teaching in a Digital Environment (TIDE) capacity construct and developing a performance-based test to measure Chilean teachers' ability to teach students how to solve information and communication tasks in a digital environment. The test was applied to a sample of 828 in-service teachers in Chile, together with a characterization questionnaire. Results showed that very few Chilean teachers mastered all the tasks and that only one third were able to provide students with orientations in solving information and communication tasks, revealing that the majority are not playing a mediation role in a digital environment. In relation to explaining variables, science and younger teachers with more years of teaching experience performed better in the test. Nevertheless the low explanation provided by the variables included suggests that variables that have previously accounted for teachers ICT integration are not as good in predicting TIDE capacity. This shows the relevance of developing mixed methods research that together with quantitative data provides qualitative data to help explain this capacity in greater depth.

1. Introduction

An increasingly technology-rich society requires that, in addition to the more traditional literacies of reading, writing and mathematics, individuals acquire a new set of skills related to the use of Information and communication technologies (ICT) or digital technologies. That is, the population should have the necessary cognitive, practical, and socio-emotional skills related to the use of ICT for their full participation in society (Ananiadou & Claro, 2009; Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014; Mossberger, Tolbert, & McNeal, 2017; Van Dijk & van Deursen, 2014; Van Laar, van Deursen, van Dijk & de Haan, 2017). This so-called digital literacy (Gilster, 1998) is considered a mindset to both easily and effectively access knowledge in different codes and

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formats (e.g., text, videos, images) in a digital environment (Fraillon et al., 2014; Martin, 2008; Van Dijk & van Deursen, 2014). As such, digital literacy is regarded an important capability for learning and participation (Hague & Payton, 2010).

Notwithstanding digital literacy's relevance, little is known about how children, teenagers, and adults become skilled in this type of literacy. Many assume that these abilities develop spontaneously and in comparison to the conventional literacies, they receive little attention from school systems (Eynon, 2010; Selwyn, 2011). However, research has shown that it is unlikely that the new generations will develop these skills without deliberate instruction (Brand-Gruwel, Wopereis, & Vermetten, 2005; Eynon, 2010; Selwyn, 2011; Walraven, Brand-Gruwel, & Boshuizen, 2008). In fact, research on information-problem solving shows that while students may have the ability to find information using digital technology, they have difficulties defining information problems, specifying proper search queries and evaluating the information they find (Brand-Gruwel, Wopereis, & Walraven, 2009; Claro et al., 2012; Walraven et al., 2008; van Deursen & van Diepen, 2013). On the other hand, teachers are increasingly asking students to use ICT and the Internet to search for information and produce reports and presentations, but these activities are not always supervised or guided by them (Hogarty, Lang, & Kromrey, 2003; Hsu, 2011; Tondeur, Van Braak, & Valcke, 2007).

As regards teachers, there is little knowledge about the competencies they should have to teach digital skills to students. Most research has focused on understanding how teachers integrate ICT in their instructional practices (Albion, Tondeur, Forkosh-Baruch, & Peeraer, 2015; Hinostroza, Labbé, Brun, & Matamala, 2011; Scherer, Siddiq, & Teo, 2015; Sánchez & Salinas, 2008) or exploring teachers' digital or ICT literacy (Ahmad et al., 2016; Markauskaite, 2007). But there is almost no research related to how they foster the development of students' digital information and communication skills in the classroom, specially within real problem-solving contexts (Siddiq, Scherer, & Tondeur, 2016). As a result of the lack of research, the field has few specific orientations to teachers and schools as to how to develop students' digital abilities for full participation and learning in the technology-rich and knowledge society.

As a way to contribute to create the knowledge base necessary to inform teaching in the digital world, the objective of this study was to define and measure teachers' capacity to teach in a digital environment (e.g., teach students how to solve information and communication tasks in a digital environment). The Teaching in a Digital Environment (TIDE) capacity construct was built taking into account frameworks collected from relevant literature (presented in Section 2) as well as information collected from two workshops with in-service teachers. Later, a performance-based test was designed to measure this capacity and applied to a sample of 828 teachers in Chile. An exploratory analysis was also performed to see if some of the teachers' general characteristics might explain their performance in the test.

2. Theoretical framework

2.1. Digital literacy

The concept of digital literacy first emerged in the 1980s. It was related to the notion of computer literacy and highlighted the need to master the incoming new technologies and their programs (Levine, 1986; Norman, 1984). Later, a broader concept of ICT literacy expanding technical ICT skills was brought to attention. This concept was advanced under a broader framework encompassing abilities and competencies now known as 21st-century skills (Claro et al., 2012; Van Laar, van Deursen, van Dijk, & de Haan, 2017). It was supported by evidence that contemporary labor markets value and reward not only those workers and professionals possessing advanced technical abilities but especially those capable to apply higher-order cognitive skills within an ICT context (Binkley et al., 2012). In the educational sector, this has brought a growing demand for training highly qualified workers possessing not only traditional literacy skills (reading, writing, and mathematics) but also abilities to solve non-routine problems and handle the type of complex information frequently present in digital contexts (Levy & Murnane, 2007).

Additionally, the concept of digital literacy has been part of an academic and policy debate related to the changing features of literacy in our culture (Beynon, 1993; Castells, 2001; Livingstone, Van Couvering, & Turin, 2008; Selwyn, 2011; Voogt, Erstad, Dede, & Mishra, 2013; Warschauer, 1998). There are at least three general features of digital literacy identified in this debate:

1) *Operating ICT.* This feature refers to 'tool literacies' (Tyner, 1998) which implies having the necessary skills to be able to use, operate and solve technology related problems –e.g., word processors, spreadsheets, navigation tools (Fraillon & Ainley, 2010; Van Deursen, Helsper, & Eynon, 2016).
2) *Working with Information.* This feature refers to the cognitive skills required to deal with the great amount of information available on the Internet, such as searching, accessing, evaluating and organizing information, as well as producing and communicating information (Ahmad et al., 2016; Claro et al., 2012; Fraillon & Ainley, 2010; Siddiq et al., 2016).
3) *Understanding digital technologies.* This feature refers to critical thinking about the role, opportunities and challenges of technology and digital media in real-world problems. It is about knowing when and why digital technologies are appropriate and helpful to the task at hand and when they are not (Binkley et al., 2012; Buckingham, 2007; Hague & Payton, 2010; Selwyn, 2011).

In summary, the concept of digital literacy has shifted from a more technical and restricted orientation based on the mastery of computer applications towards a broader perspective that includes critically using these tools to solve cognitive problems on a daily basis in order to participate in all areas of contemporary social life.

2.2. Defining and measuring teachers' ability to teach students how to solve information and communication tasks

Identifying, measuring and promoting digital skills in educational systems is a recent enterprise, and only a few countries have started to do it on a national scale. There are different approaches and definitions, but many of them focus on students' digital information and communication skills (Ananiadou & Claro, 2009; Binkley et al., 2012; Ferrari, 2013; Fraillon, Schulz, & Ainley, 2013). Nevertheless, there is scarce literature concerning the abilities teachers need to develop students' digital information and communication skills (Siddiq et al., 2016). Most teacher-related research has focused on understanding the factors explaining technology use and integration, such as general attitude toward computers and innovation, perceived usefulness, teachers' pedagogical beliefs (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Mama & Hennessy, 2013; Salinas, Nussbaum, Herrera, Solarte, & Aldunate, 2016; Scherer et al., 2015; Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017).

There are several frameworks defining teachers' ICT competencies and their professional uses (e.g., UNESCO, 2011; ISTE-T, 2017). These frameworks generally include four areas: technological appropriation, pedagogical practice, academic administration and evaluation and teacher development. However, although they offer general standards, they do not provide specific orientations for teachers' practice. One exception is the INTEF framework developed by the Ministry of Education of Spain (Ministerio de Educación, Cultura y Deporte, 2013), which defines teachers' digital competence concerning DIGICOMP definitions (Ferrari, 2013) and provides indicators that can be evaluated in each competence. More specifically, it considers the skills, attitudes, and knowledge defined for European citizens, and links them to the teachers' role. Nevertheless, this framework fails to link students' digital skills and teachers' classroom instructional practice. Such link has been made by the TEDDICS construct presented by Siddiq et al. (2016), which defines teachers' emphasis on developing students' digital information and communication skills in the classroom, by elaborating a goal-oriented conceptual framework that combines the use of ICT, teaching practice, curricular demands, and beliefs about which ICT skills are important. The construct is based on teachers' self-reports, as administered in ICILS 2013 (Siddiq et al., 2016).

3. Methods

3.1. Instrument

3.1.1. The capacity to Teach in a Digital Environment (TIDE) construct

TIDE capacity was defined as:

The teacher's knowledge, skills, and attitudes for designing, organizing, guiding and evaluating activities with explicit learning objectives and teaching criteria, with a view to developing students' ability to solve information and communication problems in a digital environment.

The definition involves two aspects or dimensions of teacher proficiency in a digital environment, that were considered relevant in teaching digital skills:

a. **Teachers' ICT Skills:** The information and communication skills and knowledge that teachers should have to perform their professional work (e.g., plan and prepare lessons) in a digital environment. These skills and knowledge were based on the skills and knowledge defined for students and adapted to teachers' lesson preparation work.
b. **Teachers' pedagogical criteria in a digital environment:** Teachers' ability to define and apply criteria and knowledge relevant to guiding students' schoolwork in a digital environment. These criteria were defined following the literature review and discussed by the research team and six in-service teachers (intentionally selected for their practices in teaching students' digital skills, each representing different school subjects).

The Teaching in a Digital Environment (TIDE) skills and pedagogical criteria were defined in relation to some or all of the 5 sub-dimensions present in the national students' digital skills for learning framework, defined by the Ministry of Education, as *the ability to solve information and communication problems, as well as ethical dilemmas in a digital environment* (Ministerio de Educación Centro de Educación y Tecnología Enlaces, 2013; Claro et al., 2012; Jara et al., 2015):

- **Information as a source.** This implies the ability to specify the information required in order to guide and restrict searches in a digital environment; develop and/or apply a search strategy to locate information in a digital environment; choose one or more sources of digital information and content based on relevance, reliability and validity criteria; arrange and structure digital information using their own or provided classification schemes to retrieve and reuse it.
- **Information as a product.** This implies specifying the necessary steps of a work plan to develop a product combining, representing, designing and integrating information in a digital environment to create a new product, idea, etc.
- **Communication.** This implies recognizing and applying social rules and norms to communicate information according to a purpose and for a specific audience; recognizing and highlighting relevant information; applying design and formatting criteria in preparing a new document, and identifying the most appropriate digital medium.
- **Collaboration**: This implies exchanging information, debating, arguing, and agreeing on decisions with others remotely or posting them with peers, teachers or others using digital tools in order to achieve common objectives.
- **Ethics and self-care.** This implies distinguishing opportunities and risks characteristics of a digital environment. Specifically, it includes applying emotional safety strategies; being aware that everyone has a right for demanding respect for his or her image and private life and to the protection of his personal data; applying strategies for the protection of personal and others'

Table 1
Skills measured and item characteristics.

Dimension	Sub-Dimension	Skill	Definition (operational indicator)	Type of item	No. of items
Teachers digital information and communication skills	Information as a source	Define the information needed	The teacher specifies the information required to answer a question or solve a problem in digital environments.	Multiple-choice	2
		Search for information	Based on the results of an information search in digital environments, the teacher restricts searches by adding keywords, using filters o other resources to refine a search (e.g., using Boolean logic (AND, OR), quotation marks, etc.)	Multiple-choice	3
		Evaluate and select information	The teacher searches the web to identify several sources of information and chooses the most appropriate one to obtain a piece of information.	Multiple-choice	2
		Organize information	The teacher organizes information into a database or list, structuring fields and columns and entering data appropriately according to the characteristics of the information and the way he/she intends to use it.	Task	1
	Information as a product	Summarize information	The teacher transforms digital information into different formats (for example, he/she creates a graph based on numerical information).	Task	1
		Create a new information product	The teacher represents and creates new information by transforming and designing texts, images and other elements using digital tools (for example, identifies and creates new information based on a database, represents information by creating graphs and designing presentations, etc.).	Task	1
	Communication	Present information	The teacher makes a presentation including a variety of resources (for example, graphs, images, text, videos or the like) to communicate information. The presentation must be neat, orderly and motivating.	Multiple-choice	1
				Task	2
	Collaboration	Collaborate with others remotely to create an information product	The teacher identifies several digital media for working in collaboration, and chooses the most appropriate for a given purpose.	Multiple-choice	2
	Digital ethics	Respect intellectual property	The teacher identifies the correct form of citing a direct quote from a piece of work (e.g., using quotation marks, following APA rules, etc.)	Multiple-choice	2
Teachers pedagogical criteria	Information	ICT teaching competencies	The teacher gives relevant directions on the use and creation of keywords.	Task	1
			The teacher gives relevant directions for choosing web pages and digital information, considering such aspects as the characteristics of various types of web sites and criteria for evaluating the reliability and validity of digital information.	Task	1
	Communication: pedagogical criteria	ICT teaching competencies	The teacher defines criteria for guiding students in the design and production of a presentation based on digital tools (for example, presentation slides).	Task	1

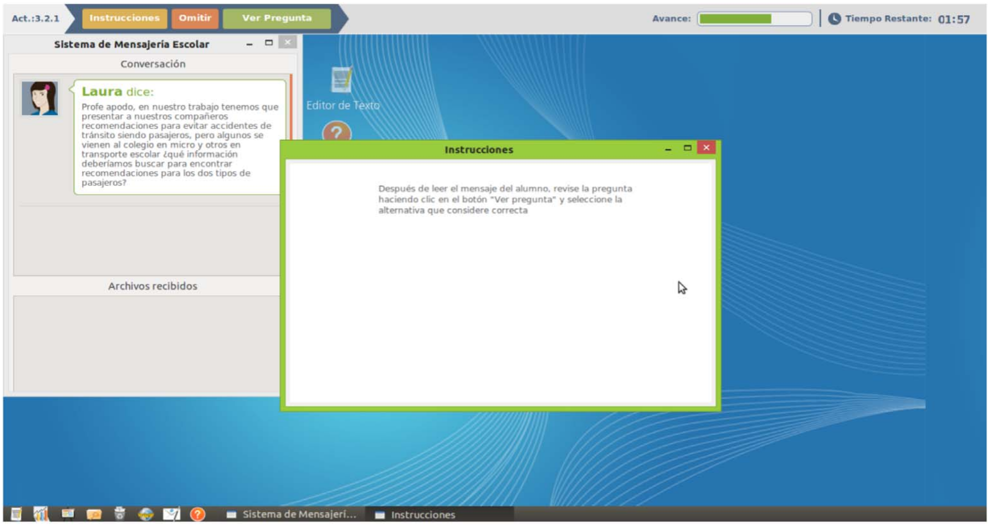

Fig. 1. Screenshot of the test environment.

information; recognizing ethical issues and the legal consequences of not respecting others' creations, and applying practices that respect intellectual property rights in the use of information resources.

3.1.2. *TIDE performance-based test*

Based on the abovementioned framework, we created the TIDE test. The test considers the dimensions and sub-dimensions described in Section 3.1 and includes a selection of skills that can be evaluated in a performance-based test. It is important to mention that evaluating pedagogical criteria was particularly challenging in a non-authentic context (e.g., outside the classroom and without the participation of real students). Therefore, as described in Table 1, pedagogical criteria includes items only in the sub-dimensions information as a source and communication, where teachers are asked to write orientations for their students to solve specific tasks.

There were two types of items: multiple-choice and tasks. Table 1 presents a summary of the skills evaluated in the test and the number and type of items designed to evaluate each skill. Additionally, teachers' attitudes towards ICT were measured in the characterization questionnaire.

The test was designed simulating a Windows environment and Office productivity software to present an interface similar to the one most commonly used in Chilean schools. The work environment displayed to teachers is a computer desktop equipped with a file browser, basic Office automation tools, an instruction window and several simulated applications including Internet access, email, and chat window. Through the chat and instructions window, respondents are asked to perform such activities as viewing web pages, creating or changing files, sending emails, or answering (open or closed) questions. All the created products and the chosen response alternatives are saved by the software-so they are subsequently corrected and analyzed. Fig. 1 presents a screenshot of the test environment.

To answer the test, teachers had to perform some activities organized in a "script" dealing with a cross-disciplinary school theme unrelated to the subject matter being taught. Teachers were expected to work in preparing the information for a Traffic Safety and Education workshop. Four general activities were designed, each of which required teachers to answer questions, perform actions or create products. The first activity required the teacher to complete and improve a digital presentation (where the abilities to create and communicate information were assessed). The second activity required the teacher to complete a student workbook where the abilities to guide students in searching for and selecting information, and preparing digital presentations were assessed. The third activity required the teacher to answer students' questions about the use of information (as a source), effective communication of digital information, collaboration in a digital environment, and ethics and self-care. The last activity required the teacher to write a report on the results of the workshop, which involved organizing and summarizing digital information.

3.1.3. *Supplementary questionnaire*

The supplementary questionnaire gathered socio demographic characteristics and educational and professional information about the teacher participants, as well as information concerning teachers' use of ICT, both on a personal and professional level, and attitudes towards the use of ICT in their teaching practice. These variables were included based on existing evidence of the variables bearing on teachers' integration of ICT to their teaching practices and learning in general (e.g., Donnelly, McGarr, & O'Reilly, 2011; Ertmer et al., 2012; Siddiq et al., 2016; Tsai & Chai, 2012).

3.2. *Sample*

A sample of 828 teachers (554 women and 274 men) from the three regions with the highest percentage of teachers in the north, central and south parts of the country took the test. The selected subjects taught science, history, language, and mathematics from the 5th to the 12th grade.

Teachers were selected using two different strategies. The first of these was stratified random sampling, with strata being defined in proportion to the number of teachers in each region, school size (regarding student registration) and subject matter taught. Schools were then randomly selected according to the defined strata, and the instrument was administered to the teachers in those schools. Information from 546 teachers was collected using this procedure. The second strategy had to be implemented due to the difficulties encountered in contacting the subjects, many of which were involved in a long-lasting teacher strike. This strategy implied a convenience sampling which consisted of inviting teachers to take the test in computer rooms fit for that purpose outside the schools' facilities. Participants were offered payment in return for their contribution to the study. A total of 282 tests were collected using this mechanism.

Since part of our sample was not selected randomly, but rather took the test on a voluntary basis, it was found necessary to test for measurement invariance between the two samples. The models are assessed according to the criteria presented by Hu and Bentler (1999) and Wu, Li, and Zumbo (2007), where a *Root Mean Square Error of Approximation* (RMSEA) < .05 is considered a good indicator of configural invariance. In order to assess the level of invariance, a difference in the *Comparative Fit Index* (CFI) of less than .01 is considered a good indicator that a certain level was reached. The results show that configural invariance is met (RMSEA = 0.049) and that a higher level of invariance is reached (all $\Delta CFI \leq .008$). In addition, *t*-tests showed no statistically significant differences between the estimated test scores of the two samples (for 'solve digital tasks' score: t (826) = .65, p = .52; for ‘develop a digital information product and provide digital pedagogical orientation’ score: t (826) = .99, p = .32). These analyses suggest that there are no significant differences between the two samples regarding the factorial structure of the test results. Since the results obtained failed to reveal significant differences between both groups of teachers, the full sample of 828 teachers was used.

Finally, it is important to state that not all the teachers who took the test answered the supplementary questionnaire (n = 655).

3.3. Characteristics of the sample

Regarding gender and age, 68% of the teachers are women, and the mean age is 38 years old (S.D. = 11). On average, teachers have 11.3 years of experience as teachers (S.D. = 9.8) and 9.4 years working at the current school (S.D. = 9.1).

The teachers are distributed across four different subjects: language (39%), math (27%), social science, geography and history (19%), and science (15%). Half of the teachers (51%) teach primary school (in the Chilean system, 5th grade to 8th grade) and the other half teaches secondary school (9th grade to 12th grade).

Most teachers have access to a computer (98%), Internet (95%) and smartphone (88%) at home, and almost half of them have a tablet (45%).

Three indicators on the teachers' use of ICT in school-related activities were calculated, adding items on a scale ranging from “I don't know this activity” (1) to “Item describes very well the activity I do in classroom” (4).

(i) Planning sessions using ICT: four frequency items (e.g., *I search for information and resources online for use during the class; I prepare lessons that involve the use of ICT by students*).
(ii) Work with students using ICT: seven frequency items (e.g., *I ask students to search on the Internet for homework or projects; I use digital resources to explain contents in class*).
(iii) Pedagogical guidance for the use of ICT by students: nine frequency items (e.g., I *teach students how to verify if the information available online is valid and trustworthy; I teach students how to describe and cite ideas or data provided by other authors in the Internet*).

Out of nine activities related to pedagogical guidance for the use of ICT by students, teachers do an average of 3.6, and there is a large variation across teachers (S.D. = 3.6). Out of four activities dealing with planning sessions using ICT, teachers do an average of 2.5 (S.D. = 1.2). Finally, out of seven activities involving work with students using ICT, teachers do an average of 2.7 (S.D. = 2.5).

3.4. Research procedure

For the application of the instruments, schools were selected from the public lists of schools available in the Ministry of Education's website (http://datos.mineduc.cl/dashboards/19731/bases-de-datos- directory-of-educational-establishments/). Schools were contacted via email and telephone. Once a date was agreed with the school, a member of the research team went to the school to apply the test and the questionnaire in the same session, using a computer provided by the project. The application of the test and the questionnaire took around 90 min.

For the application of the test and the questionnaire in the convenience sample, an invitation email was sent to teachers who met the sampling requirements. The application for this sample was made in several sessions using the University's dependencies and computers.

3.5. Psychometric properties of the Teaching in a Digital Environment (TIDE) test

This section describes the factorial structure, reliability and the properties of the items of the test.

Table 2
Test scores multivariate models.

	Model 1				Model 2			
	Solve digital tasks		Develop a digital information product and provide digital orientation		Solve digital tasks		Develop a digital information product and provide digital orientation	
	β	$SE(\beta)$	β	$SE(\beta)$	β	$SE(\beta)$	β	$SE(\beta)$
Gender	−0.90	0.87	−0.10	0.88	−0.87	0.88	−0.09	0.89
Age	−0.04	0.07	−0.14	0.07**	−0.05	0.07	−0.14	0.07*
Subject (ref. Natural Science/Biology)								
History, Geography and Social Sciences	−4.37	1.40**	−1.36	1.41	−4.24	1.41**	−1.41	1.42
Language	−3.67	1.23**	−2.36	1.24*	−3.56	1.24**	−2.35	1.25*
Mathematics	−3.70	1.30**	−0.94	1.31	−3.61	1.31**	−0.83	1.32
Type of school (ref. Public)								
Subsidized	−1.17	0.87	−0.11	0.87	−1.22	0.87	−0.02	0.88
Private	0.39	1.48	0.48	1.49	0.43	1.48	0.47	1.49
Years of teaching experience	0.01	0.08	0.16	0.08**	0.02	0.08	0.16	0.08*
Internet at home	1.31	1.87	−0.69	1.88	1.50	1.88	−0.80	1.89
Smartphone at home	0.38	1.29	0.19	1.30	0.45	1.30	−0.03	1.31
Computer at home	−1.34	3.26	−1.71	3.28	−1.08	3.27	−2.00	3.29
Pedagogical guidance for the use of ICT by students					0.12	0.16	−0.08	0.16
Planning sessions using ICT					0.15	0.41	0.29	0.41
Work with students using ICT					−0.32	0.24	0.17	0.24
Constant	105.47	4.42**	107.50	4.45**	105.05	4.50**	107.07	4.53**
R^2	0.0271		0.0142		0.0299			0.0166

Note: *$p < 0.01$ ** $p < 0.05$.

3.5.1. Descriptive analysis of items and dicotomization

As presented in Table 1, the test contained 20 items (8 task items scored as 0, 1, 2 or 3 using a rubric, where 0 means “task not achieved at all” and 3 means “task achieved completely” and 12 multiple-choice items scored automatically as 0 or 1, where 0 means “task not achieved” and 1 means “task achieved”). An analysis of teacher distribution in each possible score of the 8 task items with partial credits revealed that 6 of the items did not show decreasing monotonicity (i.e., the % of teachers obtaining a higher score is greater than the % of teachers obtaining a lower score). Also, 5 of the items had less than 30% of the teachers in the middle scores (1 and 2) (see Table 2 in the Appendix for results on the analysis of partial credit items). This suggests that the items work in a dichotomous way rather than in a polychotomous one. Therefore, the partial credit items were dichotomized for further analysis by scoring 1, 2 and 3 points as 1 point.

3.5.2. Factorial structure and reliability

Three exploratory factor analyses (EFA) using the tetrachoric correlation matrix were performed. The strategy common to these analyses was the following: (1) a 4-factor solution was first obtained; (2) the rotated solution was analyzed; (3) if one factor grouped a few of items (in our case, 2 or 3 items), a 3-factor rotated solution was estimated; (4) if a factor still grouped a small quantity of items, a 2-factor rotated solution was obtained; (5) the accepted loading was greater than or equal to 0.4 (see Table 3 in Appendix for details).

The first EFA lead to eliminate one item when a 2-factor rotated solution was obtained. The second EFA was conducted using 19 items. It was also obtained the 2-factor rotated solution: in this case, the loadings of all the items were greater than 0.5: the 8 task items grouped in factor 1 and the 11 multiple-choice items grouped in factor 2. This finding suggested the existence of two dimensions measured in the test (see table 4 in Appendix for details).

The first factor (alpha = 0.73) included all multiple-choice items, which are intended to measure the teachers' ability to apply criteria to respond to questions related to information, communication, collaboration and ethical issues involved in the development of an information product. On the other hand, the second factor (alpha = 0.83) included all task items, which are intended to measure the teachers' ability to develop an information product, as well as to provide orientations to students for solving digital information and communication tasks. Based on this result, we named the first factor ‘solve information, communication and collaboration tasks in digital environment’ and the second factor ‘develop an information product and guide students to solve tasks in the digital environment”.

The result of the factor analysis seems to be accounting for teachers' ability to respond to a certain type of item (multiple-choice versus task items) within the TIDE test. Although it does not respond exactly to TIDE dimensions, it might be showing that applying specific criteria to answer a question versus developing something (e.g., an information product and pedagogical orientations), require different cognitive skills in a digital environment. This result will be further discussed in Section 5.

3.6. Data analysis

To answer the research question, the results of the performance-based test were analyzed by using a Rasch model to estimate teachers' ability and test item difficulty. This enabled us to describe teacher distribution in detail regarding the type of items that they master.

For the exploratory analysis of teachers' characteristics, a multivariate regression analysis was performed using the scores of both test dimensions as dependent variables. Since performance in these two dimensions is correlated, it was necessary to fit a model that takes into account the correlation between each teacher's scores. Multivariate linear models or Seemingly Unrelated Regressions (SUR) (Zellner, 1962) are therefore the most appropriate statistical tool. A first model explores possible performance differences across gender, age, access to technology, type of school, years of experience as a teacher and subject matter taught. A second model explores the possible effect of other variables in connection with the teachers' ICT related work.

4. Results

4.1. Teachers' performance in the test

This section describes the results of the teachers' performance in the two factors measured in the test, first in terms of scores and second regarding what teachers demonstrated they were actually able to do in the test.

With respect to the factor ‘solve information, communication and collaboration tasks in digital environment’, an index obtained by adding the 8 binary items shows a mean equal to 4, with a standard deviation equal to 2.6; the median was equal to 5, the maximum score was equal to 8 points, and the minimum score was 0 points. Seventeen-point three percent (17.3%) of the teachers obtained 0 points whereas 6.4% obtained the maximum score. Scores were estimated by the Rasch model and standardized with a mean equal to 100 and a standard deviation equal to 10. Fig. 2 shows the density Kernel estimation of the task scores (Silverman, 1986), with a distribution skewed to the right and with a significant peak at the lowest scores, which shows that there are two teachers' performance groups: one with the lowest scores and another that starts higher in the scale and presents a normal distribution.

For the factor ‘develop an information product and provide orientation to students in a digital environment’, an index obtained by adding the 11 binary items shows a mean equal to 6.1, with a standard deviation equal to 2.8; the median was equal to 6, the maximum score was equal to 11 points, and the minimum score was 0 points. Six-point nine percent (6.9%) of the teachers obtained 0 points whereas 2.1% obtained the maximum score. Fig. 3 shows the density Kernel estimation of the scores with a distribution slightly skewed to the left and with a minor peak at the lowest scores, also showing two performance groups.

Figs. 4 and 5 below summarize the simultaneous representation of test item difficulty and teachers' ability in the two factors. The vertical axis shows the common scale that measures ability and item difficulty. Teachers' general ability in each factor is reported in percentage terms; thus, in the 'solve digital tasks' factor, for instance, in 32.4% of the cases, teachers' ability is higher than the difficulty of the item “collaborate with others” and lower than the difficulty of the item “quote another person's work”. These teachers are said to master the item “search and access digital information,” but do not master the item “quote another person's work.” This simultaneous representation also includes an accumulative aspect. Thus, for instance, the 9.2% of teachers who master the item “quote another person's work” also master all the lower difficulty items.

The Rasch model for the ‘solve information, communication and collaboration tasks in digital environment’ factor showed that Fig. 4:

- 25.6% of the teachers do not master any of the knowledge required.
- 74.4% of the teachers can define the information needed in order to answer a question or solve a problem, evaluate and select

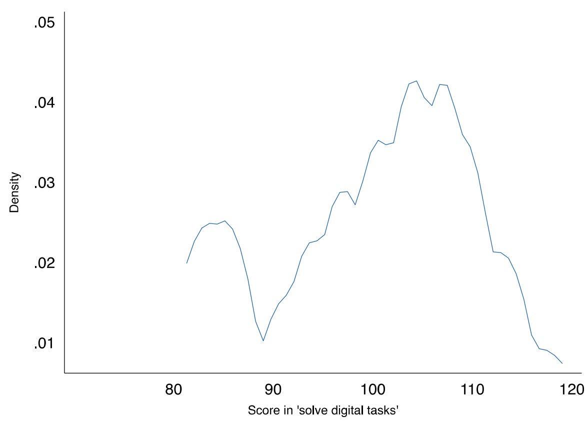

Fig. 2. Density Kernel estimation of the scores in factor ‘solve digital tasks’.

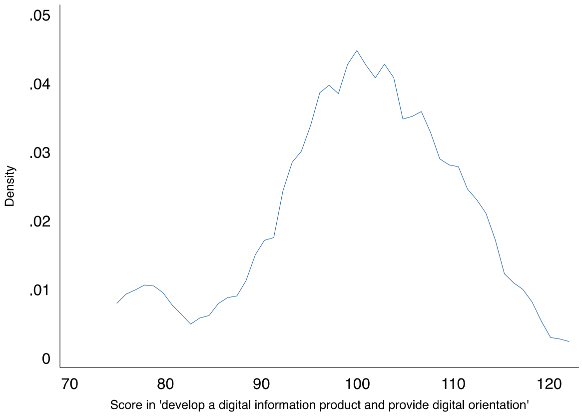

Fig. 3. Density Kernel estimation of the scores in factor 'develop a digital information product and provide digital orientation'.

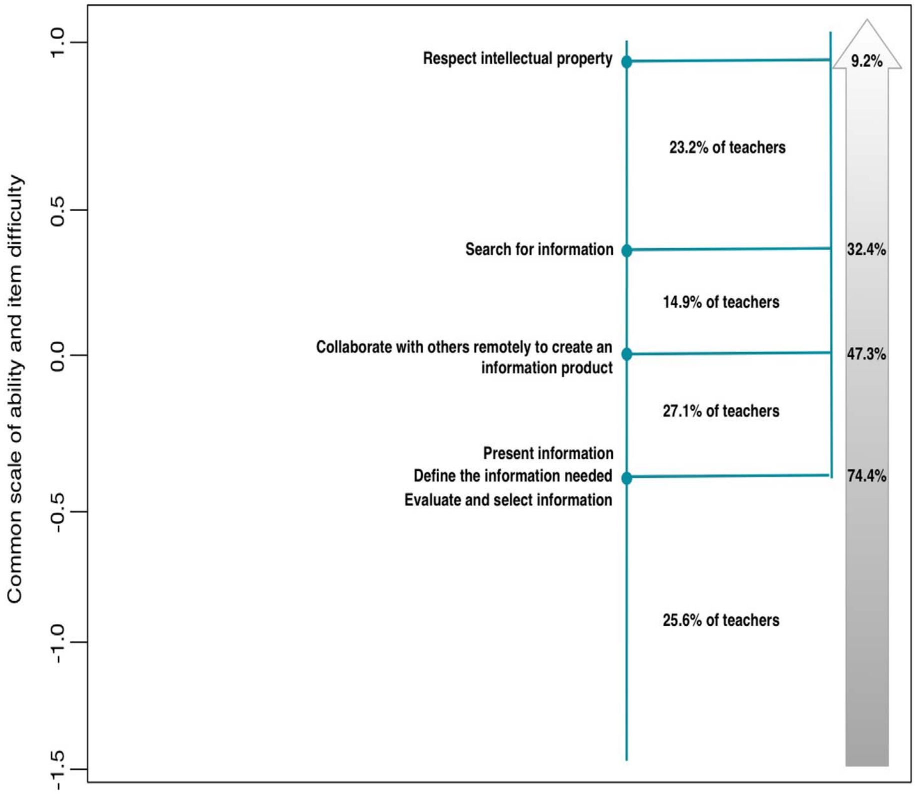

Fig. 4. Simultaneous representation of item difficulty and teachers' abilities in 'solve digital tasks' items.
Note: Accumulated percentages are presented in the gray arrow.

digital information (e.g., identify different sources for searching information online and select the most appropriate) and present information for a certain audience (e.g., identify the most appropriate type of information in order to develop a communication product).

- 47.3% of the teachers not only master previous knowledge, but also know how to collaborate with others (e.g., identify different digital media for collaborative work and select the most appropriate one for a specific goal).
- 32.4% of the teachers not only master the four previous knowledge tasks, but also know how to search and access digital information (e.g., specify keywords and filters)
- 9.2% of the teachers not only master the five previous tasks, but also know how to quote another person's work.

The Rasch model for the factor "develop an information product and guide students to solve tasks in a digital environment" showed that (Fig. 5):

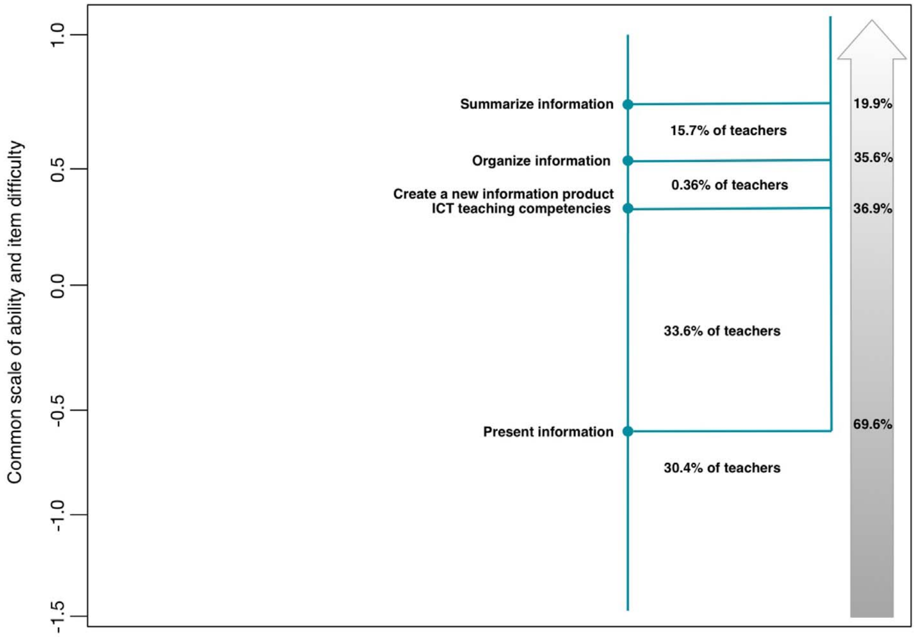

Fig. 5. Simultaneous representation of item difficulty and teachers' abilities in 'develop a digital information product and provide digital orientation' items.
Note: Accumulated percentages are presented in the gray arrow.

- 30.4% of the teachers do not master any of the tasks.
- 69.6% of the teachers can present information for a certain audience including digital resources (e.g., images, text) to communicate information clearly.
- 36.9% of the teachers not only master the previous task, but also are able to elaborate a new product in order to represent information by transforming text, images and other elements (e.g., elaborate a slideshow with information obtained online) and also master the pedagogical criteria to guide students in solving digital tasks (e.g., give advice on the use of keywords, criteria to evaluate online sources and communicate digital information).
- 35.6% of the teachers not only master the three previous tasks, but also are able to organize digital information (e.g., organize textual information in a spreadsheet).
- 19.9% of the teachers not only master the four previous tasks, but also are able to summarize digital information, transforming it into different formats (e.g., create a graph using numerical data).

The above data show that one-third of the teacher respondents are unable to perform any of the required tasks and one-fourth lack the necessary knowledge required in the test. At the other end, 20% of the teachers are able to adequately 'develop a digital information product and provide digital orientation,' and 9% can 'solve digital tasks'.

The data also show that the most difficult tasks in the 'develop a digital information product and provide digital orientation' factor are 'organize digital information differently' and, especially, 'summarize digital information, transforming it into a different format'. In terms of the 'solve digital tasks' factor, the knowledge that teachers master the least is search for and access to digital information and quoting the work of others.

4.2. Exploring performance related variables

We performed a multivariate regression analysis or Seemingly Unrelated Regressions, with the scores of both test dimensions as dependent variables. Results for the first model (see Table 2, Model 1) showed that gender and type of school had non-statistically significant effects on teachers' performance in the test. Age and years of experience working as a teacher had no significant effect on the 'solve digital tasks' items score. On the contrary, they turned out to be significant predictors of performance in 'develop a digital information product and provide digital orientation' items: age was negatively associated while experience as a teacher was positively associated ($p < 0.05$). Access to ICT (PC, Smartphone, and Internet at home) did not have a statistically significant effect on teachers' performance in the test.

In terms of the subject matter of teaching, we compared the effect of being a teacher of math, language or history with being a science teacher since the latter had the highest mean score in both dimensions (Table 2, Model 1). For the 'solve digital tasks' items score, science teachers achieved a significantly higher mean score than all other teachers. For the 'develop a digital information product and provide digital orientation' score, science teachers achieved a significantly higher mean score than language teachers ($p = 0.05$). However, these results should be interpreted with caution, since the model as a whole only explains a very small percentage of the variance of each dependent variable (R^2 of 2.7% and 1.4%, in Table 2).

Results for the second model (see Table 2, Model 2) showed that such indicators as the teachers' ICT-related work, ICT use by students and pedagogical orientation for the use of ICT by students had no statistically significant effects on teachers' performance. The statistically significant effects found in Model 1 continue to be significant with the inclusion of these variables.

5. Discussion and conclusions

This paper sought to measure Chilean teachers' level of ability to teach students how to solve information and communication tasks in a digital environment. To do this, a Teaching in a Digital Environment (TIDE) capacity construct was defined in relation to the national students' digital skills for learning framework, and a performance test was designed and applied to a sample in-service teachers. The results of a sample of 828 Chilean teachers showed that very few of them mastered all the tasks and knowledge tested and that more than one-fourth of them did not master any of them at all.

The factor analysis showed two factors or dimensions of TIDE: 'solve information, communication and collaboration tasks in digital environment' and 'develop an information product and guide students to solve tasks in a digital environment''. In relation to the first dimension, the simplest tasks were, define the information needed, evaluate and select information, and present information to an audience. It is interesting that the majority of in-service teachers (74.4%) were able to assess and select digital information, which are tasks that are commonly difficult for students (Brand-Gruwel et al., 2005; Eynon, 2010; Selwyn, 2011; Walraven et al., 2008). A possible explanation may be linked to evidence that shows that as people grow older and have a better judgment, they exhibit greater ability to evaluate and select information (Van Dijk & van Deursen, 2014). On the other hand, the most difficult tasks for Chilean in-service teachers were related to collaborating with others remotely, organizing and summarizing information, and quoting the work of others. These results are consistent with the deficiencies evidenced by Chilean students in processing information in a digital environment (Claro et al., 2012).

In relation to the second dimension, the majority of teachers (69.6%) were able to present information using digital resources, but only one third approximately, evidenced mastery of tasks related to transforming information (e.g., create a slideshow with information obtained online) and guiding students in a digital environment (e.g., give advice on the use of keywords, develop criteria to evaluate online sources, etc.). This result is relevant and should be further investigated, as it seems to show that many teachers are not playing a guiding role when students work with information online.

About the variables that might explain teachers' TIDE capacity, the data shows that the selected variables are very limited in explaining the variations in the scores teachers obtained in the two dimensions. In the case of 'solve information, communication and collaboration tasks in a digital environment', the subject matter taught is the variable which most contributes to explaining such variation. Specifically, science teachers perform better than the other teachers in the sample. A possible explanation for this is the relevance of research abilities in Science, and that nowadays research is done mostly on the Internet (Gobierno de Chile, MINEDUC 2015). In the case of the dimension 'develop an information product and guide students to solve tasks in a digital environment', age and experience have a bearing on performance, although the variance explained by the model continues to be low. Specifically, younger teachers with more years of teaching experience evidenced being more competent in TIDE. This result may be showing that the mere fact of being young and having grown up in a digital environment does not vouch for this competence. On the contrary, time spent practicing as a classroom teacher is necessary. Even though this result deserves further investigation, it is an indication that this competence needs to be trained through initial teacher-training centers.

On the other hand, the little explanation provided by the selected variables for teachers' TIDE capacity scores seems to show that the variables that have traditionally accounted for the uses of ICT in education do not look to bear on these teacher competencies little dealt with in the school system. Future research in this area would benefit from mixed research methods that, apart from yielding quantitative data, may also provide qualitative information about the characteristics of teachers that master TIDE competence. Furthermore, it would be relevant to study and learn from their teaching strategies in a digital environment to inform teacher training programs. This bottom-up strategy could complement and enrich more traditional top-down teacher training strategies.

Finally, the instrument showed good psychometric properties and is, therefore, a reliable starting point in measuring teachers' TIDE capacity. Nevertheless, it is necessary to bear in mind some limitations concerning the design of the instrument. Since factor analysis showed two factors apparently associated with method variance, it is difficult to differentiate between method variance and construct variance. Therefore, it is advisable that future versions of the instrument combine various types of items for each dimension and sub-dimension of the theoretical construct. This would help understand if the dimensions of the TIDE construct should be redefined as suggested by the empirical results in this study.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2018.03.001.

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