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Multivariate analysis of teachers' digital information skills - The importance of available resources

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ABSTRACT

Digital information skills are prerequisites for success in the information society. Previous research on 21st century skills has shown that digital skills evolve sequentially, building on digital information skills, making them the key to future skills that teachers should acquire and be able to pass on to future generations. In the research on digital skills, shortcomings of bivariate approaches have been widely identified and interest has largely shifted to multivariate methods. However, the development of effective targeted interventions still requires a deeper understanding of the social resources of individuals and the interdependencies of predictors. This study examined the extent to which sociodemographic factors and available resources predict digital information skills and which subgroups emerge as potential targets for interventions, by analysing the interdependence of the predictor variables. The empirical data used in the study consisted of 4988 Finnish teachers' questionnaire responses and performance test results. Utilising the multiple regression analysis, the study found that digital activity and age explain most of the variation in teachers' digital information skills. Their effect was found to be the inverse of each other, with abundant digital activity increasing and age reducing teachers' mastery of these skills. Digital self-efficacy and in-service training also emerged as promising predictors, highlighting that teachers' information skills are explained more strongly by the available resources than by sociodemographic factors. At the end, the practical significance and recommendations for more targeted interventions as well as for further research are considered on the basis of the results obtained.

1. Introduction

The expansion of digital technologies into areas of social, economic, and personal life have made digital information skills an important factor for success, not only in the labour market, but also in civic and social life (Ertl, Csanadi, & Tarnai, 2020; Facer & Furlong, 2010; van Deursen & van Dijk, 2016). Searching, evaluating, and processing information is an integral part of everyday life in today's information society. The more advanced digital applications become in the future, the more digital information skills will be needed (van Dijk, 2020.) According to Castells (2010), the process called *informationalisation* is visible in all professions, referring to the information itself becoming the main source of productivity in many professions. This also applies to teachers, whose basic daily duties are largely based on searching, processing and sharing information, making these skills the core competency requirements of the teaching profession.

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van Dijk (2006) has highlighted the increase in the information intensity of societies. According to him, this leads to a new kind of organisation in societies, marked by a growing importance of information products in the economic field, a growing demand for information processing skills in the labour market and an increased essentialness of information products in the field of culture. Many key functions in society are undergoing fundamental changes as a result of the effects of increased and diversified information. Rapidly evolving information technology and the growing importance of information therefore also requires changes at all levels of education (Kivinen, Piiroinen, & Saikkonen, 2016).

The demands of the information society for the adequate mastery of novel information skills have been one of the key factors in curriculum reform in many countries. In Finland, information skills (incorporated into ICT competence and multiliteracy) are part of the so-called transversal skills of the current core curriculum. The aim is to provide these skills as part of the teaching in all subjects throughout basic education (FNBE, 2016). The phenomenon-based, exploratory and problem-based learning, emphasised in Finnish national core curriculum, requires students to develop the skills to search, interpret, evaluate and manage information and to process the obtained information into a relevant output according to the respective goals. These kinds of skills are not only relevant in the context of education or working life, but diverse information skills also play a key role in the wider society as social interaction and day-to-day affairs become increasingly digitally transmitted.

As is evident from the above, information skills are the key skills that teachers should impart through education to new generations. However, teachers' proficiency as mediators of these skills varies, and current school practices are not always compatible with the goals of the information society (see, e.g., Kivinen et al., 2016). In fact, Claro et al. (2018) found that only a minority of teachers were able to provide guidance to students in solving tasks related to digital information and communication skills, revealing that the majority of teachers do not have the desired role as a mediator of this kind in the digital environment. Varying attitudes among teachers towards the use of information and communication technology in instruction, as well as differences in the adequacy of equipment in schools, predict the development of students' digital skills (Lorenz, Endberg, & Bos, 2019) thus leading to variations in students' capabilities. As a result, there is said to be a gap between the skills that children acquire through formal education and those they would actually need to live and work in the 21st century world (Lau & Yuen, 2014). Nonetheless, formal education is crucial in supporting students in developing adequate competences. This is why there is a need for teachers who are well prepared, skilled and motivated to promote the development of students' skills (see, Hatlevik & Hatlevik, 2018).

The Digital Education Action Plan 2021–2027, recently published by the European Commission (2020), emphasises that skills possessed by teachers and the sense of competence they experience are a prerequisite for transmitting the core competencies of the 21st century. Strengthening teacher capacity requires increased insight of the variation in teachers' digital information skills, with particular attention to the interdependencies and multidimensionality of the underlying factors. The aim of this study is therefore to examine the extent to which sociodemographic factors and available resources affect teachers' digital information skills. In the context of this study, resources refer to the resource factors available to individuals, such as received in-service training, digital self-efficacy and experience in the use of digital technologies. Instead of merely distinguishing between potential predictors, the present study also seeks to analyse the interdependencies of those predictors in order to identify the most vulnerable subgroups of teachers for targeted interventions.

2. Information skills and related digital inequalities

The so-called 21st century skills consists of technical skills, information skills, communication skills, collaboration skills, critical thinking skills, creative skills, and problem-solving skills (van Laar, van Deursen, van Dijk, & de Haan, 2020). According to van Laar et al. (2020), there exists a digital equivalent for each of the listed skills above. For example, digital communication skills include the ability to transmit information online (i.e., to use social media, chat, and email) while digital information skills include the ability to search for information from digital sources and evaluate the usefulness, relevance, and reliability of the retrieved information, as well as to manage digital information (i.e., manage documents, files, and emails) (van Laar et al., 2020; 2019a.).

van Laar, van Deursen, van Dijk, and de Haan (2019b) emphasise that digital skills have a sequential and conditional nature, meaning that they build on each other. Therefore, a person who does not possess one type of skill is likely to lack another as well. The sequence begins with digital information skills, followed by collaboration, critical thinking, and creative digital skills, all of which, with the exception of digital critical thinking skills, lead directly to digital problem-solving skills (van Laar et al., 2019b). For this reason, when considering teachers' digital abilities, it makes sense to develop their skills starting from digital information skills.

In the field of information research, information literacy has traditionally meant the skills of recognising a need for, searching for, acquiring, evaluating, organising and applying information (Bawden, 2001). van Deursen and van Diepen (2013) proposed a definition of information skills, which covers the selection of a search system, the definition of search queries, the selection of relevant information and the evaluation of information sources. Also, the importance of information management is emphasised in some of the definitions (e.g., van Laar, van Deursen, van Dijk, & de Haan, 2019a). The spread of information technology has changed the definitions by including in digital information skills the skills needed to process, share and communicate digital information (e.g., ACRL, 2016; Claro et al., 2018; Fraillon, Schulz, & Ainley, 2013). Information skills are intertwined with digital communication skills, which previous research specifically considers encompassing the ability to effectively communicate information to different audiences using media and online formats (van Laar, van Deursen, van Dijk, & de Haan, 2017) and the ability to share information to selected and relevant audiences across a variety of online services and networks (van Deursen, Helsper, & Eynon, 2014). In this study, the concept of digital information skills is understood in its broader meaning to encompass searching, processing and sharing information, as all these skills are increasingly central, especially in the work of teachers.

Research on digital inequality has been approached from different perspectives, starting with physical access (e.g., Howland, 1998) and diffusion of new communication technologies (e.g., Rogers, 2001) and ending with a relative view of digital inequality (e.g., Helsper, 2017). In the early years of the study of digital inequality, the conceptual focus was narrowly placed on physical access. Access meant, in particular, the ability to acquire digital media hardware and software or an Internet connection (van Dijk, 2017; 2020.). Since these early years, it has been found necessary among researchers to look at differences in use rather than differences in access. This so-called second-level digital divide research focuses on skills and usage (Büchi, Just, & Latzer, 2016; Hargittai, 2002.). More recently, researchers have been concerned about shortcomings in individuals' ability to turn their online experiences into favourable offline outcomes. This relates to third-level digital divide research concerning disparities in the returns from internet use among the population of high-technology countries (van Deursen & Helsper, 2015; van Dijk, 2020.).

van Dijk (2005, 2017, 2020) has systematically sought to compile a theory based on research evidence of digital inequality. His theory of Resources and Appropriation is a combination of structuration theory (resources) and acceptance theory (appropriation). The core arguments of van Dijk's theory can be summarised as follows: Personal categorical inequalities in society, related to frequently observed dichotomies (such as young-old, male-female), produce an unequal distribution of resources, thus causing unequal access to digital technology. However, unequal access to digital technologies depends not only on social resources but also on the characteristics (such as novelty or ease of use) of these technologies. The importance of above lies in the fact that unequal access to digital technology leads to unequal participation in society more broadly. This, in turn, reinforces categorical inequalities and the unequal distribution of resources. According to van Dijk (2005, 2017, 2020), along with the personal categorical inequalities, the positional inequalities such as labour position, education, household, and nation, contribute to better digital access for well-off individuals. Progress of digitalisation thus tends to reinforce existing social inequalities.

Previous research has found several sociodemographic factors that affect the digital information skills. There is a clear consensus among researchers that young people possess better digital skills in general and also better digital information skills than older people (Claro et al., 2018; Ertl et al., 2020; Hargittai & Shafer, 2006; Ngueng, Hunsaker, & Hargittai, 2020; OECD, 2013; OECD, 2015; van Deursen & van Dijk, 2015) and that the level of higher education predicts better skills relating to digital literacy (Hargittai & Shafer, 2006; OECD, 2015; van Deursen & van Dijk, 2009; van Deursen, van Dijk, & Peters, 2011; Kaarakainen, Saikkonen, & Savela, 2018). In contrast, there are usually no significant differences in information skills in terms of gender (Ertl et al., 2020; Hargittai & Shafer, 2006; van Deursen et al., 2011; van Dijk, 2020; Kaarakainen et al., 2018). It has been found that in urban areas, the population usually has better digital proficiency than in rural areas, as digital connectivity and the use of Internet services are poorest in deep rural areas (Mossberger, Tolbert, & Gilbert, 2006; Philip, Cottrill, Farrington, Williams, & Ashmore, 2017). van Deursen and van Dijk (2015) also point out that some social positions make it possible to practice information and other digital skills more than others, accumulating these skills more for those in information-rich or pioneering professions in society. Specifically related to teachers, little research results are available on digital information skills, especially those that would comprehensively address the above factors.

Access is by no means a dichotomous measure (e.g., van Deursen & van Dijk, 2015), it is more about the quality, familiarity, and habits of access. Helsper (2017) points out that digital exclusion is compound and multifaceted. Relying on the Relative Deprivation Theory, she recalls that it is necessary to distinguish between the absolute and the relative levels of exclusion. Scientists should focus not only on individual resources and societal factors, leading to the digital inequalities, but draw attention to meso-level factors; a person's everyday experiences and relationships that determine relative and subjective deprivation and have the potential to motivate individuals and communities to change the situation. Effective interventions take into account both objective inequality and its cognitive and affective components (Helsper, 2017.). From the perspective of developing students' digital information and communication skills, Siddiq, Scherer, and Tondeur (2016) emphasise the importance to look at the extent to which teachers emphasise these skills in the classroom in addition to the mere frequency of use of technology in teaching.

According to Helsper (2019), people live their daily lives in certain physical and social contexts and therefore do not exist in society only with their individual needs and abilities. As a result, digital inequality cannot be understood by looking merely at an individual's skills or digital accessibility, nor by distinguishing between socio-demographic characteristics. Instead, it becomes understood in those meso-level social and physical contexts where these individual characteristics and structural factors encounter. The social context can be seen as the norms, values and practices surrounding the engagement with digital technology (Helsper, 2019.). Among teachers, the integration of new technology into teaching has been found to be determined by the external pressure they experience, for example in the form of the perceptions of other members of the work community (Kreijns, van Acker, Vermeulen, & van Buuren, 2013). Hatlevik and Hatlevik (2018) recall that work communities provide not only social pressure but also social support for the use of digital technology. Both pressure and support as expressions of the social context underline the importance of Helsper's (2017) understanding of the role of digital referents: individuals assess the adequacy or inadequacy of their technology use and related skills in relation to the social conditions and their key actors to which they feel they belong.

In terms of the social context and the resources it enables for individuals, previous research shows, for example, that the frequency and versatility of technology usage, i.e., accumulated usage experience, predicts the level of digital information skills (Hargittai, 2010; Hargittai & Shafer, 2006; Kaarakainen et al., 2018). Teachers' digital self-efficacy has emerged as a key predictor for the likelihood of teachers utilising digital technology in their work (Drossel, Eickelmann, & Gerick, 2017; Gebhardt, Thomson, Ainley, & Hillman, 2019; Hatlevik & Hatlevik, 2018; Kreijns et al., 2013; Scherer, Siddiq, & Teo, 2015) and it has been found to increase after receiving in-service training in digital skills (e.g., Lee & Lee, 2014) making both of these resources essential for teachers in transferring digital information skills to students. A recent meta-analysis (Scherer, Siddiq, & Tondeur, 2019) of general technology adoption in teaching found that subjective norms, digital self-efficacy, and facilitative conditions such as social support and adequate resources affect perceived utility and ease of use and thus attitudes among teachers. The results support the earlier statement of Weiβ and Bader (2010) that in-service training should focus in particular on teachers' attitudes towards digital technology and their perceptions of their own competences.

3. Aim of the study

Given the limited availability of empirical research on teachers' digital information skills, it is justified to focus research interest specifically on this topic. In particular, the need to study these skills is emphasised by van Laar et al.'s (2019b) recent notion that these skills are prerequisites for enabling the accumulation of other digital skills. In previous research, the inclusion of social factors in the analysis is considered favourable rather than focusing only on the characteristics of individuals (e.g., van Laar et al., 2020). Researchers in the field have long stressed the need for multivariate approaches rather than mere bivariate methods (Ragnedda, Ruiu, & Addeo, 2020; van Deursen & van Dijk, 2015; Vehovar, Sicherl, Hüsing, & Dolnicar, 2006) and recently also highlighted the need to consider the interdependencies of categorical predictors (Dubrow, 2013; Ertl et al., 2020). To date, most of the studies concerning teachers' digital skills have relied only on self-report data (e.g., Gebhardt et al., 2019; Litt, 2013; Palczyńska & Rynko, 2020), recognising the problem that people tend to misjudge their digital competence (Litt, 2013; Palczyńska & Rynko, 2020).

Taking the above mentioned aspects into account, this study aims to refine the image of teachers' digital information skills and to help target interventions on the most vulnerable subgroups of teachers. Utilising data that combines self-reported survey responses and performance test results, the present study complements existing research with a multivariate approach, combining sociodemographic characteristics and the resources available to individuals, generated by meso-level social activity. Derived from these objectives, the research questions of the study are:

1. How do sociodemographic factors and available resources predict teachers' digital information skills?
2. What kind of teacher subgroups emerge as potential targets for interventions by looking at how the interdependencies of multidimensional factors divide teachers into distinct clusters?

4. Methods

4.1. Participants

The data used in this study were originally collected in a project led by the Finnish Ministry of Education and Culture, initially funded by the Finnish Prime Minister's Office (2017–2018) and further funded by the ministry (2019). The purpose was to assess the achievement of the government programme objectives and therefore to collect data over several years. However, teachers were not motivated to answer twice, which prevented the original goal of the follow-up study. As a result, the ministry ordered a new sample for the last year so that data collection would not burden the same municipalities for several consecutive years. Therefore, the data were collected in 2017–2019 in 549 schools from municipalities belonging to two representative samples of Finnish municipalities formed by the Finnish Education Evaluation Centre (FINEEC) based on municipal size and regional location. The 2017–2018 sample consisted of 68 municipalities and the 2019 sample of 69 municipalities, which in both samples is about a quarter of Finnish municipalities. Information about the study and participation links were provided to the school leaders in the sample municipalities. Based on the number of participating schools, nearly one-fourth of Finnish basic education level schools participated in the study.

Altogether 4988 teachers took part in the study, which corresponds to a little over a tenth of Finnish basic education teachers. For the few participants who responded to the test twice, the data only includes responses for the first time. Of all participants, 24% were male and 76% were female teachers. Participants were 24–66 years old, with a mean age of 46 years (*SD* 9.5). Of the respondents, 4% were under 30 years old, 24% were 30–39 years old, 34% were 40–49 years old, 30% were 50–59 years old and 9% were 60 years old or older. In Finland, class teachers are generalists and teach mainly all subjects in grades 1–6 at primary school level (ISCED level 1), whereas subject teachers teach one or more subjects in grades 7–9 at the lower secondary school level (ISCED level 2). Both class teachers and subject teachers have a university-level master's degree (Paronen & Lappi, 2018.). Based on this, the teachers were divided according to the teacher type, with the result that 51% were class teachers and 49% subject teachers.

The geographical representation of the participants was comprehensive due to the national municipal samples formed by FINEEC. The distribution of the participating teachers was examined by dividing participants according to the statistical classification of Finnish municipalities (OSF, 2020) on the basis of the urbanisation level of the place of their employment (i.e., according to the location of the schools). The majority of the teachers (64%) taught in schools located in urban municipalities, 21% of the teachers taught in semi-urban municipalities and 15% of the teachers taught in rural municipalities.

4.2. Measurement

The data was collected using an instrument called the ICT skill test that was developed in the Research Unit for the Sociology of Education (see, Kaarakainen, 2019). First, the test collected the teachers' background information (age, gender, postal code of place of employment, information on whether the teacher is a class or subject teacher). Teachers then responded to a questionnaire about their digital usage habits. The digital usage questionnaire asked participants to evaluate their usage as follows: "How often do you use digital technologies for … maintaining social relationships/communicating/running daily errands/following the news/browsing the Internet for information/creating digital content/sharing digital content/playing digital games/digital entertainment/learning". The frequency of use was rated on a scale 0 = "never", 1 = "sometimes, 2 = "weekly", 3 = "daily", 4 = "several hours per day". The digital activity variable was formed as a sum variable from these responses (Cronbach's Alpha = .72).

Teachers' self-efficacy was measured by asking them whether or not they perceive themselves as competent in the areas of digital skills (i.e., basic operations, office suite applications, communication, networking and security, content creation and sharing, and acquisition and maintenance of applications and computational thinking) related to their work. The self-efficacy variable is thus a sum variable of the binary responses (does not feel or feels competent in the content area) normalised on a scale of 0–1, describing an individual's digital self-efficacy as a whole on a scale of none–completely (Cronbach's Alpha = .83). Teachers were also asked if they had received adequate in-service training in the above content areas in relation to the requirements of their profession, and the in-service training sum variable was constructed using the same scale and method as described above (Cronbach's Alpha = .86).

The performance-based test consists of 15 test items, each producing a maximum of 2 points. Each item combines several interactive, matching, multiple choice and multiple-true-false tasks, and thus none of the items is dichotomous in nature. This study focuses on the 9 digital information skills related items of the test (see, Appendix A) used to form the digital information skills sum variable (Cronbach's Alpha = .78) covering areas familiar from the previous literature: Retrieving information (test item: information searching and evaluating), processing information (test items: word processing, spreadsheets, presentations, image processing, video and audio processing), and sharing information (test items: social networking, digital communication, cloud services and publishing). With regard to the test items of which the concept of information skills in this study is formed, appendix A presents evidence for the appropriate item difficulty and the sufficient discrimination power. Likewise, the item-total correlation values indicate valid internal consistency. Appendix A also provides evidence that item characteristics are comparable across gender, indicating proper measurement invariance. The data with the variables defined in this section are stored anonymised in their raw form in the general open access data repository, Zenodo, for long-term storage and further use (Kaarakainen & Saikkonen, 2020).

4.3. Analysis

At first, the suitability of multilevel modeling was tested. However, according to the unconditional model, the variation of teachers' information skills takes place almost 100% at the individual level, leaving no basis for such modeling. Thus, multiple linear regression was chosen as the more appropriate approach in relation to the available data. Before the actual analyses all the variables were normalised by the min-max scalar method to a scale of 0–1, and deviating values were removed from the normalised variables, making them comparable and more suited for further statistical analysis. At first, a correlation table (Pearson's correlation) was created to examine the descriptive statistics and preliminary interrelations of variables. In the correlation table, the actual age was used instead of the normalised age. Evaluation of the missing values showed that the missingness was unsystematic and was therefore left untreated, leading to the exclusion of those cases from the related analyses.

The multiple linear regression allows the effect of multiple independent variables on the variance of a continuous dependent variable to be examined. The multiple regression analysis is an extension of simple linear regression. The model for the multiple linear regression is formulated as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \varepsilon$$

In the equation, y is the dependent variable and x is the independent variable. Notation $\beta 0$ refers to the constant or the intercept, $\beta 1$ represents the slope (beta coefficient) for $x1$, etc. Finally, ε is an error term meaning an unexplained variation that occurs as a random factor in a dependent variable. In regression analysis, the model parameters (β_0, β_1, β_2, $\ldots\beta_p$ and ε) are estimated from the data. It should be noted that multiple regression analysis allows for relationship analysis, but association within variables does not necessarily imply a causation. (Nathans, Oswald, & Nimon, 2012; Yan & Su, 2009).

The multiple regression analysis assumes that the observations are independent (i.e., independence of residuals), the relationship between the dependent variable and each independent variable is linear, the data shows homoscedasticity (i.e., the size of the error term remains the same between the values of the independent variable), but not multicollinearity (i.e., independent variables should not correlate strongly with each other), there are no significant outliers, and the residuals (errors) are approximately normally distributed (Yan & Su, 2009). All the assumptions were fulfilled after the preprocessing described above. Analyses were performed with IBM SPSS Statistics software (version 25).

Multiple linear regression analysis was performed in this study to predict teachers' information skills (dependent variable) based on several independent variables, which were classified into two groups: sociodemographic factors (gender, age, municipality group, teacher type) and available resources (digital activity, self-efficacy and in-service training). The model was built using a block-wise approach. The first model includes only the sociodemographic factors and the second model includes both the categorical factors and available resources. Root mean square error and R squared scores were applied to compare the models.

K-means clustering was used to identify teacher subgroups, emphasising the interdependence and multidimensionality of influencing factors. It is a centroid-based partitioning method designed to divide the data so that each observation belongs to a cluster using the nearest mean (cluster centers). In this way, the aim is to minimise Euclidean distances between clusters, but to achieve a clear distinction between groups (Han, Kamber, & Pei, 2011.). The clustering utilised those variables that proved to be statistically significant predictors of information skills by regression analysis (model 2). The interdependencies of the variables producing the subgroups were also visualised as a two-dimensional representation.

5. Results

The descriptive statistics for the examined variables and their correlations are presented in Table 1. Teachers achieved an average of 64% (standard deviation, $SD = 0.155$) of the maximum points in the sum variable of information skills. Male teachers performed somewhat better than female teachers as they achieved an average of 67% ($SD = 0.171$) of the maximum points compared to an average of 63% for female teachers ($SD = 0.149$). Two thirds of the teachers thought that their digital skills sufficiently corresponded to the requirements of their work, thus possessing a sense of self-efficacy. Only one third of the teachers reported that they had, based on their own judgment, received adequate in-service training in digital skills in relation to the requirements of their profession.

When examining the correlation of the variables, several interesting observations were made. Gender had only a minor association with the examined variables (in favour of males), whereas age had a clearly occurring negative relationship with all the other variables excluding the urbanisation level and teacher type. The urbanisation level of the location of the teacher's place of employment and teacher type did not correlate with any of the variables considered. Digital activity was found to associate to a considerable extent with all the other examined variables except gender, teacher type and urbanisation level. In particular, it correlated positively with teachers' self-efficacy and their digital information skills. Self-efficacy in itself had a positive relationship with digital information skills and especially with in-service training. Thus, the factors that associated most with the information skills were age ($r = -.41$) and self-efficacy ($r = 0.41$), with opposite effects, while digital activity ($r = 0.35$) and in-service training ($r = 0.31$) were the next most closely related variables. The lowest association to information skills was observed with urbanisation level and teacher type.Where the correlation indicates a bivariate association between variables, the regression reveals that the observed outcome actually depends simultaneously on one or more of the other variables. Thus, a multiple linear regression was conducted to examine the relationship between teachers' information skills and both sociodemographic factors (gender, age, municipality grouping, teacher positioning) and available resources (digital activity, self-efficacy and in-service training). Table 2 represents the two executed models: the first model includes only sociodemographic factors and the second model additionally includes available resources. Both models proved to be significant, but when comparing the explanatory power of the models (Model 1: adjusted $R^2 = 0.16$; Model 2: adjusted $R^2 = 0.30$) and their residuals (Model 1: RMSE = 0.135, Model 2: RMSE = 0.124), Model 2 proved to be better fitted to the data. The R^2 change of these two models also turns out to be statistically significant at the 0.01 level, confirming the choice of the latter model.

Considering Model 1 ($F(4, 2581) = 122.747$, $p < .001$), which contains only the sociodemographic factors, the best predictor of information skills among teachers seems to be age, which has a significant decreasing effect on teachers' information skills. Gender (being a male) and teacher type (being a subject teacher in lower secondary education level) also appear to be minor but significant predictors of information skills. In contrast, the urbanisation level of a teacher's location of employment is found to be inconsequential to teachers' information skills in Finland.

For the final solution, Model 2, the significant regression equation was found to be $F(7,2578) = 154.200$, $p < .001$, with R^2 of 0.30. In this equation, teachers' predicted information skills are equal to 0.517 + .328(digital activity) - 0.163(age) + 0.087(self-efficacy) + 0.022(in-service training) + 0.011(teacher type) + 0.009(gender) - 0.006(urbanisation level), showing that digital activity, age and digital self-efficacy explain most of the variation in teachers' information skills. Of the predictors, digital activity ($\beta = 0.24$, $p < .001$), age ($\beta = -0.24$, $p < .001$), self-efficacy ($\beta = 0.22$, $p < .001$), in-service training ($\beta = 0.05$, $p = .011$), and teacher type ($\beta = 0.04$, $p = .019$) are significant, whereas gender and urbanisation level are not. When the available resources were added in model 2, gender, which was found to significantly affect the outcome variable in Model 1, lost its significance as a predictor of information skills. The negative effect of age remained significant, but its effect diminished slightly after the available resources were taken into account.

Based on the statistically significant predictors of Model 2 (age, digital activity, self-efficacy, in-service training, and teacher type), teachers were clustered into six subgroups. The number of clusters was reached by experimenting with different values of k (2–8) and observing the ability of the formed clusters to distinguish subgroups of teachers with distinct levels of digital information skills (see Appendix B). Clusters 1–3 describe high-skilled teachers and clusters 4–6 low-skilled teachers. Cluster 1 consists of teachers mainly under the age of 30 who are digitally active and have a high self-efficacy. Cluster 2 consists of teachers with an average age of 35, who have good self-efficacy and high digital activity. In this cluster, male teachers are over-represented in relation to their actual proportion. Cluster 3 consists of early middle-aged teachers with average self-efficacy and digital activity. The first low-skilled subgroup (cluster 4) resembles the third group in terms of digital activity and self-efficacy, but is particularly composed of middle-aged female teachers who have received significantly less in-service training in digital matters compared to their more skilled colleagues. Cluster 5 is characterised by the over-representation of men in relation to their share in the data and especially the low self-efficacy and the low

Table 1
Descriptive statistics for variables and their correlations.

Variables	*N*	*M*	*SD*	1	2	3	4	5	6	7	8
1. Gender[1]	4988	.24	.43	1							
2. Age	4988	46.06	9.49	.03	1						
3. Urbanisation level[2]	4988	.74	.37	.02	-.05**	1					
4. Teacher type[3]	4988	.49	.50	.05**	-.02	-.04**	1				
5. Digital activity	4943	.50	.11	.06***	-.26***	.02	.03*	1			
6. Self-efficacy	2674	.61	.37	.19***	-.30***	.03	.08***	.31***	1		
7. In-service training	2661	.35	.38	.18***	-.20***	-.01	.07***	.24***	.65***	1	
8. Information skills	4877	.64	.16	.10***	-.41***	-.00	.07***	.35***	.41***	.31***	1

*$p < .05$.
**$p < .01$.
***$p < .001$.
[1] 0 = female, 1 = male.
[2] 0 = rural, 0.5 = semi-urban, 1 = urban municipality.
[3] 0 = class teacher, 1 = subject teacher.

Table 2
The multiple linear regression analysis of the predictors of digital information skills.

	Model 1					Model 2				
Independent Variables	*B*	*SE*	*β*	*t*	*p*	*B*	*SE*	*β*	*t*	*p*
(Constant)	.781	.009		83.216	.000	.517	.016		32.000	.000
Gender[1]	.034	.006	.101	5.577	.000	.009	.006	.027	1.617	.106
Age	-.261	.012	-.284	−21.216	.000	-.163	.012	-.240	−13.476	.000
Urbanisation level[2]	-.003	.007	-.006	-.358	.720	-.006	.007	-.014	-.853	.394
Teacher type[3]	.018	.005	.063	3.461	.001	.011	.005	.039	2.349	.019
Digital activity						.328	.025	.238	13.316	.000
Self-efficacy						.087	.009	.217	9.530	.000
In-service training						.022	.009	.055	2.543	.011
R	.400					.543				
R^2	.160					.295				
F	122.747					154.200				

[1] 0 = female, 1 = male.
[2] 0 = rural, 0.5 = semi-urban, 1 = urban municipality.
[3] 0 = class teacher, 1 = subject teacher.

level of received in-service training. The weakest subgroup (cluster 6) consists of late middle-aged teachers, who are characterised by low self-efficacy, low digital activity, and low levels of participation in digital in-service training.

Fig. 1 illustrates interdependencies within the independent variables as a two-dimensional representation while still expressing the main distinguishing factors of the multidimensional cluster solution. Figure shows the overall decline in digital information skills, activity and self-efficacy with age. This is also manifested in the cluster solution, where cluster 1 consisted of the youngest participants with the strongest skills, and the oldest teachers with the weakest skills formed cluster 6. Figure also shows that digital activity and age, are not only related to each other, but their interrelation also expresses differing patterns according to gender. The decline in digital activity among male teachers is somewhat stronger associated with aging than among female teachers. Yet, the clearest differing pattern is seen in digital self-efficacy: male teachers' perceptions of the adequacy of their digital skills in relation to their work is higher than female teachers and particularly high for the three youngest age groups, but decreases sharply with aging. These patterns produce the cluster 5 with many male teachers from the age group 50–59, who share poor information skills and low levels of digital self-efficacy.

The amount of in-service training received decreases with age, with the exception of male teachers aged between 30 and 39, who participate in such training more than other teachers. This is evident also from the cluster 2, with many digitally active and capable male teachers. Participation in in-service training remains particularly low for middle-aged female teachers manifesting in the cluster 4. It is worth noting that the correlation between in-service training and information skills increases with age: in the age group over 60

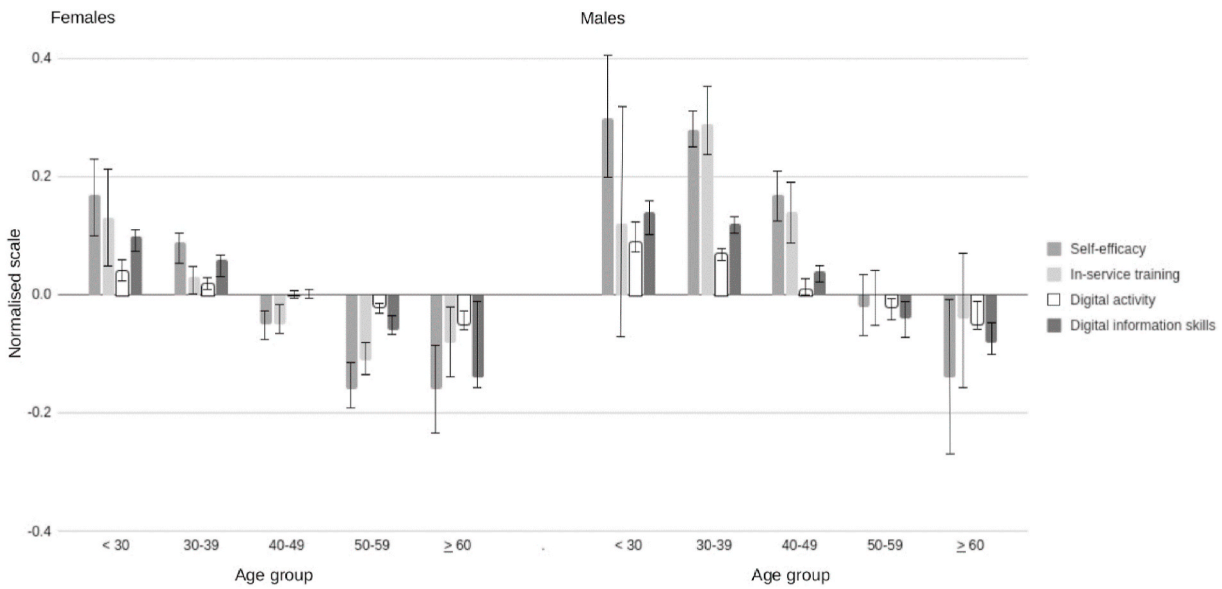

Fig. 1. Age-group-specific digital self-efficacy, in-service training, digital activity, and digital information skills by gender presented as deviations of group means from the sample mean on a normalised scale, supplemented by a 95% confidence interval.

the correlation is clearly the strongest ($r = 0.45$), in the age groups 30–39, 40–49 and 50–59 the bivariate correlation is slight but still evident (ranging from $r = 0.25$ to 0.28), whereas in the age group under 30 the correlation remains negligible ($r = 0.11$).

6. Discussion

The aim of this study was to identify how sociodemographic factors and available resources predict teachers' digital information skills. This was approached by using multiple regression analysis to examine the effects of sociodemographic factors (gender, age, urbanisation level of the place of employment, teacher type) and available resources (digital activity, self-efficacy and acquired in-service training in digital skills) on the Finnish teachers' digital information skills. Based on the results, digital activity and age explain most of the variation in teachers' information skills. Their effect transpires to be the opposite of each other, as abundant digital activity increases and aging decreases teachers' mastery of these skills. These results are in line with previous research, showing that digital usage experience, accumulating from digital activities, predicts the level of digital information skills (Hargittai, 2010; Hargittai & Shafer, 2006; Kaarakainen et al., 2018) and that young people generally have better digital skills compared to older people (Ertl et al., 2020; Hargittai, Piper, & Morris, 2019; van Deursen & van Dijk, 2015).

After digital activity and age, the next promising predictors for teachers' digital information skills are experienced self-efficacy and received in-service training in digital topics. These factors have been widely examined, and previous research evidence emphasises that teachers' digital self-efficacy has a strong positive association with the use of information technology in their instruction practices (e.g., Drossel et al., 2017; Hatlevik & Hatlevik, 2018; Kreijins et al., 2013), and that teachers' digital self-efficacy can be increased particularly by in-service training (e.g., Lee & Lee, 2014). It is therefore not surprising that in the present study, the strongest bivariate correlation is found between self-efficacy and in-service training. However, with regard to in-service training, the present study stresses that when controlling for other variables, the clear bivariate correlation between in-service training and digital information skills decreases. This suggests that the association between in-service training and teachers' digital information skills is likely to be indirect, and mediated through improved self-efficacy.

When examining for sociodemographic variables other than age, current results suggest them having only minor direct relevance to teachers' digital information skills. The teacher type, whether the teacher is a class or subject teacher, affects teachers' information skills to some extent as subject teachers in lower secondary level are observed to have slightly better skills than their class teacher counterparts in primary school level. Gender as an independent explanatory variable is not observed having a significant impact on teachers' digital information skills. Previous research supports the low significance of gender as an independent predictor of such skills (Hargittai & Shafer, 2006; van Deursen et al., 2011; Kaarakainen et al., 2018). Correspondingly, this study does not support the assumption of a rural-urban divide (see e.g., Philip et al., 2017).

In addition to identifying significant predictors of teachers' digital information skills, the aim of this study was to determine which subgroups emerge as potential targets for interventions. Such a closer examination of the key factors identified by the regression analysis revealed a more in-depth picture by considering the interdependencies of the predictor variables. The importance of such examination has been highlighted in previous studies (e.g., Dubrow, 2013) suggesting that the more unfavourable sociodemographics a person represents, the more disadvantaged they are in terms of their resources. Therefore, Ertl et al. (2020) emphasise the need to examine the interdepencies of categories such as gender and age in order to get closer to an understanding of multiple digital inequalities as it, according to Else-Quest and Hyde (2016) seeks the meaning of belonging to several social category simultaneously. In the present study, such an analysis allows the identification of the most vulnerable teacher subgroups.

The cluster analysis that took into account the interdependencies of the predictor variables revealed that the most vulnerable subgroups among teachers are teachers over the age of 60, regardless of gender. In addition, interventions should be targeted at female teachers right after the age group 30–39 as well as male teachers over the age of 50. The oldest of these vulnerable subgroups suffers from the most severe lack of digital information skills, but all of these subgroups report low participation in in-service training in digital topics. Of particular concern, however, is the low level of digital self-efficacy in these subgroups, which is likely to undermine these individuals' interest in digital technology in general and thus hampers their ability to develop digital skills at a later stage.

The decline in digital activity among male teachers is somewhat stronger associated with aging than among female teachers. The abundant digital activity of male teachers is particularly focused on those under the age of 45. This, manifested through cluster analysis, highlights that male teachers are not a homogeneous group; rather there are disparities among male teachers based on their age. The same effect of age is also evident in male teachers' perceptions of their own digital competence in relation to the requirements of the teaching profession: digital self-efficacy is particularly high for the youngest age groups, but decreases sharply with aging after they turn 40. Despite this, in general, male teachers' digital self-efficacy is somewhat higher than female teachers' in all age groups which is not surprising, as women's lower levels of digital self-efficacy have been revealed in numerous previous studies (Gudmundsdottir & Hatlevik, 2018; Hargittai & Shafer, 2006; Nikolopoulou & Gialamas, 2016; Palczyńska & Rynko, 2020; Umar & Yusoff, 2014).

According to the results of the study, in-service training currently appears to be cumulating for young males as male teachers aged 30 to 39 stand out by receiving significantly more in-service training than any other group. This is probably due to selection based on personal preferences, as in Finland teachers' autonomy also extends to professional development (Salokangas, Wermke, & Harvey, 2020). Targeting in-service training at the most vulnerable groups of teachers would presumably be quite effective, according to the results of this study showing that the importance of in-service training on teachers' digital information skills increases with age.

This study provides also indications of what in-service training should focus on. As digital activity strongly predicts teachers' digital information skills, in-service training should seek to inspire and encourage teachers' digital engagement beyond the mandatory requirements of their profession. According to Ertl et al. (2020), in terms of overall digital problem-solving skills, high digital activity partially compensates sociodemographic factors such as age. Therefore, it can be assumed that particularly more versatile digital experiences could increase both digital skills and self-efficacy among those subgroups of teachers who are lagging behind in digital engagement for the time being.

Helsper (2017) points out that most interventions and in-service training focus on individuals and take place separately from their everyday social situation. This is often not very efficient, as individuals' perceptions about the importance of digital engagement for themselves are greatly determined by their surrounding social referents. Therefore, feelings of digital deprivation, or wealthiness, are socially contextual depending on the persons an individual uses as a point of reference (Helsper, 2017.). Helsper (2019) recommends that effective interventions should be built not only on objective inequality, but in particular on its cognitive and affective components. In the teaching profession, meaningful digital referents consist of members of the work community. Therefore, in order to improve the digital information skills of teachers, actions are required simultaneously at two levels; efforts should be made to raise awareness of the importance of mastering 21st century skills among all teachers in the work community and to target interventions to the least prepared subgroups of teachers.

It is also important to encourage group activities and facilitate social support, rather than seek change by increasing knowledge at the individual level. Asmar, van Audenhove, and Mariën (2020) have recently explored the importance of social support for digital inclusion. Their concept of social support refers to the different habits of individuals to cope with learning in constantly changing situations. They highlight that support networks are not only used when individuals encounter difficulties, but support is also sought in a preventive way. Asmar et al. (2020) stress that the strength of the relationship between individuals and the level of intimacy are important predictions to apply for support. It can be assumed that a widely shared understanding of the importance of digital skills at the work community level is likely to encourage individuals to invest in their own learning and promote self-actualising peer support among work communities. Therefore, in-service training should seek to influence these digital referents in community level to promote the action potential of individuals at the local level and thus facilitate wider change in education.

7. Limitations and future research

The methodological limitations in this study can be specified as related to sampling as well as instruments and concepts. The sampling has been implemented at the municipal level with the aim of geographical coverage, but it does not guarantee the representativeness of individual level participants in relation to the level of digital skills and experience of the Finnish basic education teachers, as it leaves room for selection bias. Especially when the management of the selected municipal schools was allowed to choose whether to pass on the invitation to participate to their staff and ultimately the individual teacher made the choice whether to participate in the study or not. However, the geographical coverage of the participants as well as the gender and age distribution are desirable, and the sample size is relatively large in relation to the situation in Finland.

Because the test instruments contained self-assessment questions, there are inevitably certain uncertainties present, for example, from the honesty of the respondents and the accuracy of their assessments to the response bias (Palczyńska & Rynko, 2020; Paulhus & Vazine, 2007). In this study, self-assessment problems have been reduced by utilising performance-based tests to measure digital information skills.

One fundamental difficulty in the field of digital skills relates to concepts and operationalisation. Definitions of digital skills and their components are constantly being redefined. As Claro et al. (2018) point out, the definition of digital literacy is part of the academic debate that is currently taking place around the changing features of literacy in our culture. This research contributes to this by redefining how digital information skills are understood. Conceptual diversity may not even be avoidable, as technology advances, often in unpredictable ways, research is constantly challenged to address these new aspects that force us to accept, at least to some extent, the diversity of concepts. For example, recent trends (Falloon, 2020) call for teachers to be able to develop young people's skills to make use of diverse digital resources and information in a safe, secure and sustainable way influencing the definition of digital information skills and the requirements for teaching these skills.

Further, the shortcomings of this study suggest that future research needs to focus more on social factors instead of mere individual characteristics. The details left unclear in this study call for, school-level information on digital resources, local digitalisation leadership and its strategic objectives, as well as social norms and forms of social support at work community level. Similar needs have emerged also in other recent studies as, for example, van Laar et al. (2020) state that research on digital skills is generally limited to individual level personal and psychological factors, avoiding issues of social determinants such as social support. In addition to emphasising the use of multivariate methods (Ragnedda et al., 2020; van Deursen & van Dijk, 2015; Vehovar et al., 2006) and highlighting the analysis of interdependencies of variables (e.g., Dubrow, 2013; Ertl et al., 2020), there is also a need for multilevel methods in future studies. Generally, multilevel modeling is an appropriate approach to data where information on participants is organised at more than one level (i.e., is nested, as is the case in educational research settings). Multilevel approach is important for drawing reliable conclusions about the independent significance of individual predictors as well as identifying grouping effects and their explanatory power. Such an approach would clarify how factors and grouping effects at different levels affect the variation in teachers' skills and to what level different kinds of targeted interventions should be focused in order to be effective.

8. Conclusion

The study found that teachers' digital information skills are explained more strongly by available resources than by sociodemographic factors. In terms of both practical actions and future research, this research provides a meaningful starting point, as education authorities have the opportunity to manage the resources available, while sociodemographic factors as such inevitably fall outside their sphere of influence. In this study, there was a particular interest in the subgroups of teachers to whom targeted in-service training should be directed. The findings of the present study emphasise that teacher characteristics do not produce one-dimensional divisions, but rather multidimensional positions that should not be assumed to be constant over time. This interdependence of the multidimensional multivariate factors underlying skill variation emerges as a methodological outcome to be considered in future research on digital inequality.

The digitalisation of society and education has a global potential to lead to an increase in the importance of the teaching profession. Moreover, the teaching profession can be seen as the kind of social position that van Deursen and van Dijk (2015) see as pioneering professions in information society. However, seizing this opportunity requires teachers around the world to be able to reap the benefits of digitalisation and widely available information. Authorities should therefore seek to promote a common understanding of the importance of digital information skills and actively target skills interventions to the teacher subgroups most in need, rather than relying on volunteering and self-direction, to raise general skills levels and in particular to reduce skills gaps among teachers. Here it should be noted, as van Laar et al. (2019) recall, that digital skills interrelate having a sequential and conditional nature. Therefore, interventions should aim to promote continuums building sequentially on each other in a way that contributes to the development of different skill areas, and thus leads teachers' towards broad possession of digital skills.

Credit author statement

Both authors have participated in the conceptualization and design of the research, development of methodology, and writing (drafting and revising) the manuscript.

Declaration of competing interest

None.

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Appendix A. The ICT skill test

Table A.1
Descriptions and item design of the ICT skill test and results of item analysis.

Item	Item description	Item design	*M (SD)*	*P*	*D*	*r*
Information searching and evaluating	The item measures skills related to the selection of information source and the evaluation of the relevance and reliability of search results.	MC	1.73 (.32)	.86	.35	.40
Word processing	The item measures text editing skills.	INT	1.42 (.68)	.71	.79	.45
Spreadsheets	The item measures skills related to filling and editing spreadsheet cells.	INT	1.01 (.64)	.51	.79	.45
Presentations	The item measures the skills related to the functions of the presentation software.	M	1.01 (.73)	.50	.92	.50
Image processing	The item measures the skills related to the functions of image processing software and the file formats related to vector graphics.	M, MTF	.84 (.46)	.42	.56	.50
Video and audio processing	The item measures skills related to the functions of video processing software as well as lossy audio compression.	MTF, MC	1.23 (.57)	.61	.64	.52
Social networking	The item measures skills related to the uses of social networking services as well as their security.	MC, M, MTF	1.23 (.44)	.62	.52	.52
Digital communication	The item measures skills related to sending email and attachment as well as understanding what information can be used to identify Internet users online.	INT, M	1.59 (.48)	.80	.52	.50
Cloud services and publishing	The item measures skills related to the features of cloud services and limiting the content of video services to a desired target audience.	MTF, MC, TF	1.06 (.62)	.53	.81	.48

P = Item difficulty index.
D = Item discrimination index.
r = Item-total correlation.
MC = multiple-choice, M = matching, MTF = multiple true-false, TF = true-false, INT = interactive.
Item score range 0–2. The formula for item difficulty index suggested for non-dichotomous items and a general formula for item discrimination power, where grouping is based on the commonly used 27%, are presented in a paper by Tiruneh, De Cock, Weldeslassie, Elen, and Janssen (2017).
The source code of the test application with test content is available at Zenodo: Kaarakainen, M.-T. (2019). The source code of the renewed ICT Skill Test application; Finnish version. Zenodo. Doi: 10.5281/zenodo.2621306.

Table A.2
Results of item analysis across the gender factor.

	Female teachers			Male teachers		
Item	*M (SD)*	*P*	*D*	*M (SD)*	*P*	*D*
Information searching and evaluating	1.75 (.29)	.87	.32	1.66 (.38)	.83	.42
Word processing	1.44 (.67)	.72	.76	1.34 (.67)	.67	.84
Spreadsheets	1.01 (.63)	.51	.77	1.02 (.67)	.51	.84
Presentations	1.01 (.72)	.50	.90	1.02 (.76)	.51	.96
Image processing	.79 (.44)	.39	.53	.98 (.49)	.49	.60
Video and audio processing	1.18 (.55)	.59	.62	1.38 (.58)	.69	.67
Social networking	1.22 (.43)	.61	.50	1.27 (.49)	.63	.58
Digital communication	1.60 (.47)	.80	.51	1.58 (.51)	.79	.55
Cloud services and publishing	1.02 (.62)	.51	.80	1.18 (.63)	.59	.76

P = Item difficulty index.
D = Item discrimination index.

Appendix B. Cluster analysis

Table B.1
ANOVA-table of k-means cluster analysis.

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	p
Digital activity	.452	5	.011	2605	42.782	.000
Age	41256.324	5	3.544	2605	11642.217	.000
Self-efficacy	7.159	5	.122	2605	58.647	.000
In-service training	3.182	5	.137	2605	23.265	.000
Teacher type[1]	.598	5	.249	2605	2.400	.035

[1] 0 = class teacher, 1 = subject teacher.

Table B.2
Final cluster centers.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Digital activity	.55	.55	.51	.49	.48	.45
Age	29	35	41	48	54	60
Self-efficacy	.80	.77	.67	.53	.48	.47
In-service training	.48	.46	.39	.29	.27	.28
Teacher type	1	1	0	0	1	0

Table B.3
Descriptive data for clusters produced by k-means clustering.

Descriptive dimension	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Number of cases	199	398	661	649	455	249
Digital information skills	.76	.74	.69	.64	.61	.57
Age	29.2	34.7	41.1	48.0	54.4	60.3
Gender ratio,% (f/m)	80/20	72/28	74/26	81/19	70/30	70/30
Teacher type	.55	.52	.45	.46	.52	.49
Digital activity	.55	.55	.51	.49	.48	.45
Self-efficacy	.80	.74	.69	.64	.48	.47
In-service training	.48	.46	.39	.29	.27	.28

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