# Development of digital fluency scale: Validity and reliability study

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## Abstract

Digitally fluent teachers are expected to contribute to the growth of digitally fluent students. The purpose of this study is to develop a valid and reliable Digital Fluency Scale to determine the digital fluency of pre-service teachers. To create an item pool to develop a scale for digital fluency, the opinions of the focus group meeting participants were gathered by a qualitative method. After the pilot implementation of scale, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were applied. Data were collected from undergraduate students at a state university in Turkey to conduct for EFA (n: 302) followed by CFA (n: 274). The scale structure with 3 factors and 29 items was revealed. The scale explains 54.65% of the total variance. It was concluded that the Chi-square value ($\chi 2$ = 1189.10, df = 371, p <0.001) was moderately significant when the fit indices of the model tested with CFA were examined. It is seen that the other fit values for the model are within the acceptable fit value ranges. Higher scores from the scale indicate a high level of digital fluency.

Keywords: Digital fluency, pre-service teachers, digital literacy, critical thinking

## Introduction

In order to succeed in today's social, cultural, and professional life, individuals must represent themselves effectively in the digital world. As the digital skills acquired for this purpose may lose their validity over time, they should be constantly refreshed with new experiences (Briggs & Makice, 2011). Digital literacy should be included among the basic literacy skills that teachers and students should learn (McGrail & Davis, 2011). Digital literacy should not be regarded as a series of technical skills that can only be used in the digital world. It also covers abilities and attitudes (Traxler, 2018). For example, Jimoyiannis (2015) proposed framework which includes operational skills, information skills, strategic skills, and digital culture and identity. It is described that digital literacy is defined as the ability to perform basic computer operations (Ng, 2012). On the other hand, using digital technologies creatively and productively to achieve desired results is referred to as “digital fluency” (Canchola-González & Morales, 2020). Thus, digital fluency is thought of as a more advanced level of skill than that required for digital literacy (Fields & Hartnett, 2018). Digital fluency is used to accentuate high-level digital skills (National Research Council, 1999).

Although many researchers have proposed definitions of digital fluency, no single definition has been agreed upon (Wei et al., 2020). Digital fluency includes critical thinking skills (Chou & Chiu, 2020; Liu et al., 2018), knowing when and where to use technology productively (National Research Council, 1999), using digital tools for expression by learners (Hsi, 2007), adapting technological changes during life (Pinho & Lima, 2013), having ability to use technology for social interaction, collaboration, and connection (Ross, 2015), achieving the desired outcomes with technology (Briggs & Makice, 2011). Demir and Odabaşı (2016) defined digital fluency from a pragmatic standpoint, incorporating definitions from the literature:

> *Ability to think critically about ICT concepts and applications, to use ICT effectively and efficiently, to have quality ICT experiences, to manage complexity, to produce solutions, to think*

*abstractly about ICT, to adapt quickly to technological transformation, to be able to employ appropriate skill sets and to flexible ICT, ability to use it for different purposes is defined as digital fluency (Demir & Odabaşı, 2016, p. 375).*

## Theoretical framework

There are numerous models and frameworks that present digital fluency in various ways. Wang et al. (2013) proposed a seven-factor model to explain digital fluency (organisational factors, demographic characteristics, psychological factors, social influences, opportunity, behavioural intention to use, and type of technology). The digital fluency framework, which is proposed by Penn State, characterized by three subfluencies such as storytelling fluency, maker fluency, and information fluency (Fleming et al., 2021). Beetham (2015) proposed a model which consists of six elements (creation, innovation and scholarship; communication, collaboration and participation; information, data and media literacies; digital learning and self-development; digital identity and wellbeing; IT proficiency). The New Zealand Ministry of Education has a model which includes three levels (Fields & Hartnett, 2018). Digital proficiency is the first level which represents knowledge. Digital literacy is the next level which represents understanding. Digital fluency is the last and upper level which represents wisdom. Silva (2018) identifies five digital competencies for digital fluency: content creation, data protection, networking, virtual resilience, and teamwork. Behar et al. (2020) identified knowledge, skills, and attitudes for digital fluency with a focus on mobile learning. Sinay and Graikinis (2018) proposed a four-stranded digital fluency model. In this model, each strand has two digital competencies: digital foundation (cognitive and critical), digital participation (collaborative and communicative), digital production (confident and creative), and digital citizenship (cultural and civic).

When definitions, models, and frameworks are examined, it is clear that digital fluency encompasses a very broad range of topics in the digital world (Behar et al., 2020; Beetham, 2015; Fields & Hartnett, 2018; Fleming et al., 2021; Silva, 2018; Sinay & Graikinis, 2018; Wang et al., 2013). There are various approaches to gaining digital fluency. Spante et al. (2018) states that a positive attitude toward technology, as well as technological knowledge and skills, for achieving digital fluency. Despite this technology-focused approach, Park (2017) states that the offline consequences of digital fluency should be highlighted as well as online. Similarly, it demonstrates that defining the need (Fleming et al., 2021) is based on some offline practises for gaining digital fluency, such as adhering to disciplinary norms and adopting a growth mindset. Rich experience is thought to be important in maintaining and improving digital fluency throughout life (Briggs & Makice, 2011). According to Spencer (2015), fluency stands for “unconscious competence” stage, which is the highest order. This stage represents the top-level learning which is mentioned as high-level expression of skills in several digital fluency definitions (Ilomäki et al., 2016). The European Digital Competence Framework for Citizens (DigComp) includes eight proficiency levels from foundation to highly specialised (Carretero, Vuorikari & Punie,, 2017). Especially, highly specialized level focused on creativity of people. In order to be at this level, one should be able to solve complex problems with digital tools, guide others in this regard, and contribute with professional practice. From these perspectives, there are similarities with digital fluency.

### *Significance of the study*

Digitally fluent individuals; demonstrates skills in evaluating, distinguishing, learning and using information technologies in accordance with their personal and professional activities (National Research Council, 1999). Nowadays, individuals are supposed to know when, when and how to use this knowledge, rather than only knowing the information (Lind & Boomgaarden, 2019). In the sense of the need for digitally fluent individuals, the digital skills needed in new educational approaches such as the 'STEM' (Bernacki et al., 2020) and 'Maker' movements (van Holm, 2017), the need to teach ICT concepts, not software, adaptation to evolving advanced digital skills, not just 'literate' users, but data-based 'knowledge'.

Teachers need to effectively incorporate emerging technologies into their teaching processes when educating the new generation born in the digital world (So et al., 2012). The teaching strategies of teachers who lack institutional help are considered to have a negative impact on the road to digital fluency (Pinho & Lima, 2013). It is thought that the lifelong learning needs of individuals would increase if the expected skills needs increase at the expected pace in the future (Howieson, 2003). In this scenario, the successful incorporation of technology that can take place in classrooms requires technical competence and self-confidence (Krumsvik, 2008). At this point, it is critical for pre-service teachers to keep their digital skills up to date to be innovative in educational contexts (Tang, 2021). These skills were important for pre-service teachers to follow current trends in their professional disciplinary field (Pinto-Santos et al., 2022). In internalizing the digital world, educators will provide learners with a more interesting learning experience (Yoder, & Terhorst, 2012). When it is expected that teachers will prepare students for new challenges in a rapidly changing world, it is once again evident that the quality of the education system depends on the quality of teachers who have capability to serve online or offline (Paniagua, 2018; Vlachopoulos & Makri, 2021). Digitally fluent pre-service teachers are required to be able to contribute to the teaching of digitally fluent students (Duncan-Howell, 2012). Although in-service training and lifelong learning continue throughout the active professional life of teachers, it is considered important to develop the technopedagogical competencies of pre-service teachers during the undergraduate studies. Resnick (2002) said that digital fluency would be a pre-qualification for having a job, engaging in society and lifelong learning at a time when the Internet is still in its infancy. On the other hand, the scale items about digital fluency have become outdated in the face of developing technology in the literature (Green, 2005). In the related study, it is seen that the items referred to as high-level digital competencies reflect digital competencies at the entry level today (Porlán, & Sánchez, 2016).

There are many developed scales aim to measure digital literacy in general (Bayrakcı & Narmanlıoğlu, 2021; Liza & Andriyanti, 2020; Ng, 2012; Ocak & Karakuş, 2018; Pala & Başıbüyük, 2020). However, none of these studies addresses digital fluency of pre-service teachers. As it is known, digital fluency is positioned as a more advanced skill than digital literacy (Fields & Hartnett, 2018). There are very few scales in the literature that aim to measure digital fluency (Chou & Chiu, 2020; Green, 2005). The scale developed by Green (2005) with 314 participants aged 21-82 focused on the use of e-mail, computers, and websites at a basic level. This scale, which can measure high-level digital skills according to the period it was developed, seems to have lost its validity today. The target audience of the scale developed by Chou and Chiu (2020) is preadolescents (secondary school 6th grade students). As can be seen, a scale that can measure the digital fluency of pre-service teachers has not been found in the literature. It is necessary to establish an assessment standard for students and teachers to measure their levels of digital fluency (Chou & Chiu, 2020). In this context, it is important to develop a valid and reliable scale to determine the digital fluency of pre-service teachers. The main purpose of this study is to develop a valid and reliable scale to determine the digital fluency of pre-service teachers.

## Method

### *Research design*

The purpose of this study was to create a valid and reliable Digital Fluency Scale, then test its validity and reliability using sequential exploratory mixed method approach (Creswell, 2014). According to the approach, the major construct to be examined in this study was pre-service teachers' digital fluency levels. A large literature review and expert opinions were used to create an item pool. Following the Likert scale, the item format was developed. The field experts evaluated the generated items, and the initial scale was created. Using EFA and CFA, the generated scale was assessed for validity and reliability, and the final version was determined to be a reliable Digital Fluency scale. Graphic representation of the research design can be found in Figure 1.

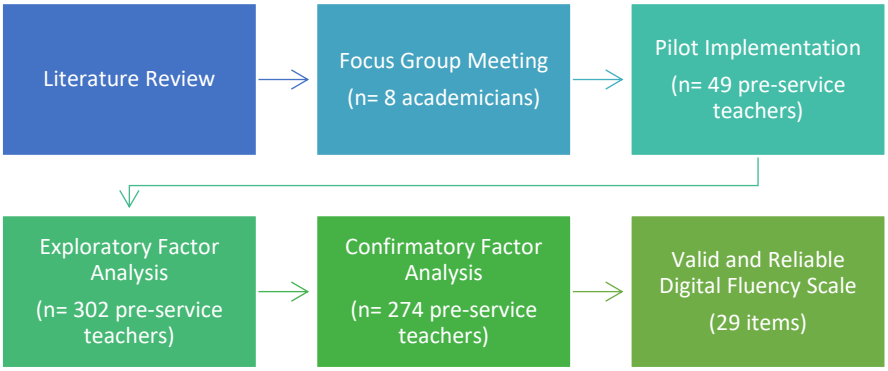


**Figure 1. Research design**

## *Participants*

Different sampling techniques were employed at different stages while determining the participants of the study. The participants of the focus group meeting, which was carried out with the aim of creating an item pool to develop a scale for digital fluency, were determined using homogenous sampling technique. Homogenous sampling, which is one of the purposeful sampling techniques, is the case where only a homogenous subgroup is selected in accordance with the desired purpose (Ayres, 2007). In cases where homogenous sampling technique was employed, focus group interviews were specified as the basic data collection technique (Palinkas et al., 2015). In the study, it was ensured that academicians who had studies on digital fluency concept and who were in the same environment with pre-service teachers were included as focus group participants. The explanation why the focus group interview participants were chosen from the CEIT department is because of their high degree of digital fluency. Information and consent form was given to each participant in the focus group interview, which clearly lays out the information on the interview and the conditions for participating in the study, and their participation was provided on a voluntary basis. Eight academicians working in a state university participated in the focus group meeting held for the digital fluency scale in 2017.

Typical case sampling technique has been used for the scale pilot implementation, which will be carried out to test the comprehensibility of the scale. Typical case sampling is the selection of a typical or normal circumstance from many situations in the universe in relation to a research problem (Teddlie & Yu, 2007). The pilot implementation of the scale was carried out on a small group in order to assess the comprehensibility of the scale in the early stages of the development of the data collection tool. In this study, the measurement tool planned to be developed was tested with 49 pre-service teachers who were studying at the 3rd grade at undergraduate level at a state university in Turkey in the fall term of 2017-2018 due to their similar characteristics with the target audience.

After the pilot implementation of the digital fluency scale, the data collection phase was started in order to carry out the validity and reliability analysis of the data collection tool. At this stage, pre-service teachers who were continuing their education at undergraduate level at a state university in Turkey were determined as samples for exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). The distribution of pre-service teachers who participated in the data collection process for EFA, according to the departments, is given in Table 1.

## *Focus group interview*

The data obtained from the participants at the focus group meetings was influenced by the interaction of the participants with each other. Group dynamics have the power to change the scope and depth of participant responses (Nyumba et al., 2018). The intended situation is to summarize the data obtained with the aid of questions previously established by the expert in order to expose the views

**Table 1. Distribution of EFA data according to departments**

| Department | Women | | Men | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| CEIT | 12 | 3.95 | 17 | 5.59 | 29 | 9.54 |
| Educational Sciences | 29 | 9.54 | 17 | 5.59 | 46 | 15.13 |
| Mathematics and Science Education | 122 | 40.13 | 52 | 17.11 | 174 | 57.24 |
| Social Sciences and Turkish Education | 32 | 10.52 | 23 | 7.57 | 55 | 18.09 |
| **Total** | 195 | 64.14 | 109 | 35.86 | 304 | 100.00 |

and attitudes of the participants on a particular topic (Colucci, 2007). A focus group meeting was held with an 8-person participant group consisting of academicians, and academicians' views on the concept of digital fluency were collected. Communication was made via e-mail in order to provide information about the focus group meeting and to invite the participants. Reasonable dates were given as a choice to the participants. The most requested date was set as the date of the meeting of the focus group.

### *Data collection tools*

The focus group meeting, which took place at 14:00 on 10 March 2017, was held in the meeting room of the Faculty of Education to make the participants feel more relaxed. The meeting room is designed as an area where participants can sit comfortably around the table, take notes and make eye contact with the researcher. During the focus group meeting, two voice recorders were kept on the table. The audio files obtained with the voice recorder were edited with the open-source Audacity tool and made ready for processing. The interview began when the researcher presented basic details and the consent document was signed by the participants indicating the empirical use of the data to be collected from each participant and the conditions for participating in the study. Later, the aim is for the participants to have an opinion on the research in general. After explaining the purpose of this focus group meeting and the general activity process to the participants, the researcher started the focus group discussion. During the focus group meeting, which lasted approximately 77 minutes, four questions were asked to the participants.

Themes and codes were developed by analyzing the data collected using the content analysis process. Although qualitative data was subject to a content analysis process, an experienced field expert working as a lecturer in the CEIT Department worked on content analysis. The themes were independently developed by the researcher and the expert. The reliability of the data was attempted to increase by offering a consensus on the themes. Inter-expert reliability was reached above.70. When the content analysis studies are analyzed, this value is seen to be at an acceptable level. The concept of verifiability is used in qualitative analysis instead of the concept of objectivity (Moon & Blackman, 2014). For this purpose, a confirmatory study on qualitative data was carried out by a content analysis specialist employed as a lecturer in the CEIT department. The focus group interview questions were prepared by the opinion of the researcher and three different field experts working as a faculty member in the CEIT department.

### *Digital fluency scale draft form*

A digital fluency scale draft form consisting of 47 items was created using the themes and codes obtained from the literature review and the focus group interview. An expert opinion form was created in order to benefit from expert opinions during the Digital Fluency Scale development phase. It was made ready by benefiting from the opinions of nine field experts (2 professors, 2 associate professors, 1 doctor lecturer, 1 doctor, 1 lecturer and 2 research assistants) who work in the

departments of CEIT, Guidance and Psychological Counseling, Turkish Language and Measurement and Evaluation. Scale items were prepared in 5-point Likert type. While the participants are asked to rate the scale from 1 to 5; 1 means "I totally disagree"; 2 means "I don't agree"; 3 means "Partially Disagree"; 4 means "I agree" and 5 means "I completely agree". Information on the relevant literature used as a basis for writing the scale items is given in appendix 2.

### *Data collection process*

Participants required for EFA and CFA were voluntarily included from a state university in Turkey who were continuing their education at CEIT, Educational Sciences, Mathematics and Science Education and Social Sciences and Turkish Education departments. After the necessary research and ethics committee permissions were obtained, the scale was applied to pre-service teachers.

### *Ethical procedures*

The current research data was obtained within the scope of the project which supported by Anadolu University Scientific Research Projects (Project Number: 1702E041). Ethics committee application and permission for the research was received from Anadolu University on May 9, 2018 (Protocol Number: 54584). Students' responses to data collection tools for research are completely voluntary.

## Findings

### *Focus group interview*

The first question in the focus group discussion, "What does the concept of digital fluency evoke?" Although three of the participants claimed that they had learned this term for the first time, the three participants stated that they had experienced the concept of digital fluency before but did not know a precise meaning of the concept. Four participants did not provide any detail as to whether they had any prior knowledge of the definition. Participants replied to the question in the areas of problem-solving skills, digital literacy skills, digital intelligence, and fluidity.

Although the participants identified their connection with the concept of digital fluency, they considered the concept to be a problem-solving skill. In addition, the participants reflected on the concept of digital fluency regarding the concept of digital literacy. All of the participants who responded with this point of view defined the concept of digital fluency as the individual's existing digital literacy skills to work to reach a solution to a problem.

> CN: *"In digital fluency, without any question marks or errors in technology, using technology in order to achieve the desired outcomes, in other words, to achieve the goal by using what is needed, that is, it is completely evident in me that there is no problem, no problem, and it is efficient and sufficient…"*

In addition, a large majority of the participants who replied (f= 3) commented that the concept of digital fluency is an upper-level concept of digital literacy.

> TO: *"We call it digital literacy and digital fluency. As a Turk, there is a good level of knowing and speaking English. But there are also native speakers. We say, you know, one person can speak like a native speaker. Is digital fluency the native speaker of digital literacy? Is it a more senior user?".*

Two of the instructors stated that when they first heard about the concept of digital fluency, they associated it with the concept of digital wisdom, which has been discussed for a relatively long time in the literature.

> TO: *"Is it wisdom or is it someone who can transfer their old knowledge by adding their old knowledge, solve problems very easily, use them fluently, or is it defining these skills?".*

**Table 2. Themes and codes of answers to the first question**

| Theme | Code | f |
|---|---|---|
| Problem solving skills | Transferring digital literacy skills to the existing problem situation | 4 |
| | Problem solving skills | 3 |
| Digital literacy skills | A higher skill of digital literacy skills | 3 |
| | Using digital technologies fluently | 2 |
| | Using digital technologies correctly | 1 |
| Wisdom | Wisdom | 3 |
| Fluency | Fluency | 1 |
| | Continuous | 1 |
| | Persistence | 1 |

One of the participants stated that the concept of digital fluency itself physically evokes the concepts of continuity, uninterruption and fluidity in moving a liquid from one place to another.

> CN: *"When I think of digital fluency, it comes to mind that it flows without interruption. In other words, like a liquid flowing in a stream or stream. It comes as a fast flow by finding new ways to reach its goal even if it is stuck…".*

The first question of the focus group discussion, "What does the concept of digital fluency evoke?" The themes and codes revealed by analyzing the answers to the question are given in Table 2.

The second question of the focus group discussion is "How would you define the concept of digital fluency?". Five of the instructors stated that they saw this concept as an upper concept of digital literacy, while two participants expressed it as a sub-concept of digital wisdom. In addition, participants answered under the themes of higher digital literacy, necessity-oriented 21st century skills, problem solving, questioning, transferring, critical thinking, synthesizing, and digital wisdom.

> TO: *"Being able to use it critically in the definition of this literacy includes a critical questioning skill. Although we think of a tool as being able to use digital tools when we say digital literate, what we perceive in the literature, when we look at the definition, it actually includes the ability to criticize and question".*

The second question of the focus group interview is "How would you define the concept of digital fluency?". The themes and codes revealed by analyzing the answers to the question above are given in Table 3.

**Table 3. Themes and codes of answers to the second question**

| Theme | Code | f |
|---|---|---|
| Higher digital literacy | Digital literacy skills | 1 |
| | A higher concept of digital literacy | 5 |
| | A sub-concept of digital wisdom | 2 |
| | The upper level of digital literacy | 1 |
| Necessity oriented | Different leveling | 1 |
| | Ability to transfer | 4 |
| | Correct, effective and fluent use of digital technologies in line with a goal/requirement | 1 |
| 21st century skills | Computational thinking skill | 1 |
| | Inquiry skill | 1 |
| | The ability to synthesize | 1 |
| | Critical thinking skills | 3 |
| Digital wisdom | Continuous use | 1 |
| | The philosophical state of digital natives | 1 |

**Table 4. Themes and codes of answers to the third question**

| Theme | Code | f |
|---|---|---|
| Innovation | Following new technologies | 1 |
| | Self-updating | 2 |
| Problem solving | Using technology effectively in problem solving | 2 |
| | Aware of digital risks | 1 |
| Readiness | Having theoretical knowledge about technology | 1 |
| | Using technology effectively | 1 |
| | Dominating different digital tools | 1 |
| | With a high level of readiness | 1 |
| | Highly motivated | 1 |
| Digital literacy | Able to transfer existing information | 2 |
| | Digital native / Digital non-immigrant | 2 |

The third question of the focus group interview is "What characteristics should an individual have in order to be qualified as a digitally fluent individual in daily life?" is the question. While two of the participants stated that they should be individuals who can transfer their existing knowledge, two participants stated that they should be digital natives. In addition, participants answered under the themes of innovation, digital literacy, intrinsic motivation, readiness, transferability, problem-solving and risk analysis. The themes and codes revealed are given in Table 4.

> TO: *"Or, when a new technology comes to hand, it can be a new social media, it can be a new tool, when it comes to a new tool, any digital tool, person should be able to use it comfortably after one or two hours of tampering with the previous information".*

In the last question of the focus group interview, the participants were asked "What are the problems you face in becoming a digital fluent individual?". Faculty members discussed the problems they encountered in becoming digital fluent individuals under the themes of internal factors, external factors and domain-specific factors.

The participants focused on needs and experience issues under the theme of internal factors. All faculty agree that an individual must have a need to put these skills to work as a prerequisite for developing digital fluency skills. All faculty members focused on the sub-theme of experience, which expresses the lack of theoretical knowledge and experience, interacting with technology. Five of the participants mentioned that their lack of experience with a new technology or the updating of existing technologies hinders them in developing their digital fluency skills.

> UJ: *"But sometimes I can't. Let me give an example from myself, I have to make a material on a specific subject. For example, I know Flash. I can say to myself that I am literate, but I am not fluent, so I cannot do as I want. Can I learn? I can learn... Yes, yes. Previous experiences, information important."*

Under the sub-theme of experience, three of the participants stated that the lack of theoretical knowledge could be an important problem in structuring new knowledge and indirectly in developing digital fluency skills.

> GJE: *"It may be involved in another dimension. In this example, field knowledge is very important. Facing a new situation, developing strategies and getting ideas from others, looking at other examples and solving them. Field knowledge is of course very important for all these."*

Motivation, on the other hand, was expressed by instructors as a problem faced by instructors in developing their digital fluency skills.

CN: *"Let me tell. I want to improve my digital fluency, but I am lazy. My motivation is running low, I don't want to learn."*

**Table 5. Themes and codes of answers to the fourth question**

| Theme | Code | f |
|---|---|---|
| Internal factors | Motivation | 5 |
| | Inactivity | 2 |
| | Feeling adequate | 1 |
| | Resistance to self-improvement | 2 |
| | Requirement | 3 |
| | Anxiety | 3 |
| | High self-belief | 1 |
| | Interest | 1 |
| | Previous experiences | 8 |
| External factors | Not getting expert support from the environment | 1 |
| | Not taking risks in digital environments | 1 |
| | Security in digital environments | 1 |
| | Time constraints | 3 |
| | Social environment | 1 |
| Domain-specific factors | Rapid change of field | 1 |
| | Frequent updates | 1 |
| | Width of the field | 1 |
| | Area-specific challenges | 1 |

The fourth question of the focus group interview is "What are the problems you face in becoming a digital fluent individual?". The themes and codes revealed by analyzing the answers to the question are given in Table 5.

As a result of the focus group discussion, it was observed that the academicians tended to try to explain the concept by analogy with the concept of digital literacy, positioning the concept between digital literacy and digital wisdom, and found themselves dominating digital literacy features. They expressed the features of digital fluency as features suitable for the fields of professionals on digital fluency features that should be in every individual in the society. Literature research, inferences from focus group interviews, themes and codes contributed to the creation of digital fluency scale draft items.

### *Pilot process*

Typical case sampling technique was used for the scale pilot implementation to be carried out in order to measure the comprehensibility of the scale. Typical case sampling is the collection of a typical, natural or common case from a large number of situations in the universe associated with a research problem (Seawright, 2016). In order to test the comprehensibility of the scale planned to be developed in the early stages of data collection tool development, the scale pilot application is carried out on a small group. The measurement tool was tested with 49 pre-service teachers because they had similar characteristics to the target group and it was found that the scale items were acceptable in terms of the relation with the entire scale. The measurement tool was given in printed form. Participant were informed via consent form which clearly explained research process to participants. The data were collected in the spring term of 2017-2018.

### *Exploratory factor analysis (EFA)*

Following the pilot implementation of the digital fluency scale, the data collection process was initiated in order to carry out the validity and reliability analysis of the data collection tool. Pre-service teachers who were studying at undergraduate level at a state university in Turkey were determined as participants for EFA and DFA. Having 304 participants to perform EFA on the 47-item form of the

Digital Fluency Scale is considered to be good according to the proposed sample size criteria in the literature (Catell, 1978; Comrey & Lee, 1992; Ledesma et al., 2015; Tabacnick & Fidell, 2007).

The data collected from the participants via printed form were analyzed and the missing values were checked prior to the study. Three types of solutions are suggested before conducting a factor analysis: estimation of missing values in the data set, extraction of rows containing missed values, and calculation of missed values by correlation matrix (Çokluk et al., 2014). Before the EFA was carried out, the estimation of the missing values was completed using the linear interpolation method (Terry et al., 1986). Statistical values are derived as a result of the tests to determine the suitability of the data to the EFA in terms of sample size. These values are expressed as the KMO test and the Bartlett test of sphericity. KMO value is considered to be bad between 0.50-0.60 values, weak between 0.60-0.70 values, medium between 0.70-0.80 values, good between 080-0.90 values and excellent above 0.90 values (Teoh et al., 2010). The significance of Bartlett's test result shows that the items are interrelated and the data come from the multivariate normal distribution. (Watson, 2017). These values were KMO = 0.946, $\chi 2$ = 9532,61, p = 0.00. The KMO value of the 47-item Digital Fluency Scale draft form was considered to be excellent. Bartlett test result was found to be significant (p=0.00). The findings show that the data collected are suitable for factor analysis.

Principal component analysis method was used in this study. Factor rotation operation aims to rotate the factor axes by moving the positions of the variables in the factor space (Çokluk et al., 2014). Factor rotation method is used to improve the simplicity and clarity of the structure of the factor (Suthakorn et al., 2020). In this study, the maximum variability (varimax) technique was chosen amongst vertical rotation methods (Ledesma et al., 2015). The main reason for performing EFA is expressed as the purpose of summarizing information and reaching original information by moving from a large group of variables (items) to a smaller group of variables (factors) (DeVellis, 2016). The guidelines to be used when deciding how many factors should be determined in the factor analysis are the eigen values and the scree plot graphs (Larsen & Warne, 2010). In order to determine the number of factors by looking at eigenvalues, values with eigenvalues of one or more are considered significant (Ledesma et al., 2015). According to the first factor analysis, 7 factors with an eigenvalue above 1 explain 62.542% of the variance in scale scores. It was mentioned that the scree-plot graph was the other significant guide for determining the number of factors. The scree-plot graph helps to reduce the factor by revealing the dominant factors (Steger, 2006). Break points in the scree-plot graphs are a guide for the determination of the number of important factors. When the graph of the scree-plot is observed, it is shown that the slope begins to display horizontal movement after the third factor. The researchers decided that the 3-factor structure obtained as a result of the repeated analyses performed was the most suitable theoretically and practically.

The factor loading values, which explains the relationship of the items in the scale with the factors, takes values between 0 and 1. While it is a common belief that the loading limit can be accepted as 0.30 when deciding on the number of factors, it is also stated that values of 0.40 and above should be taken. (Yamamoto, 2014). In this study, the lower limit point of load was determined as 0.40. Items with a difference of at least 0.1 in factor loading values were excluded from the scale by considering them as overlapping items. 18 items were removed from the scale as a result of the analysis. Scale structure with 3 factors and 29 items was obtained as a result of EFA. Descriptive statistics regarding scale factors and items are presented in Table 6.

The item loadings ranged between 0.492 to 0.824. Common variance values vary between 0.701-0.301. The scale explains 54.65% of the total variance.

As a consequence of EFA, scale factors were defined and items under the same factor were statistically examined. As indicated in the beginning, frameworks relating to digital fluency were studied during this process (Behar et al., 2020; Beetham, 2015; Fields & Hartnett, 2018; Fleming et al., 2021; Silva, 2018; Sinay & Graikinis, 2018; Wang et al., 2013). Awareness, self-efficacy, and affective were determined as scale factors. The items under the awareness factor were found to be connected to the

**Table 6. Factor and item statistics**

| | Factors | | | $\bar{x}$ | ss | Common Variance |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | | |
| **Awareness (α=.922)** | | | | | | |
| I can produce digital content in the quality that I want in an original way. | 0.794 | | | 3.165 | 0.9574 | 0.639 |
| I can be a role model in using digital tools. | 0.738 | | | 3.388 | 0.9987 | 0.567 |
| I have enough interest to improve my digital skills. | 0.722 | | | 3.426 | 0.9818 | 0.623 |
| I have the necessary motivation to develop my digital competencies. | 0.693 | | | 3.477 | 0.9472 | 0.546 |
| I can think abstractly in relation to computer concepts. | 0.639 | | | 3.421 | 0.9184 | 0.495 |
| I can understand the way search engines generate results. | 0.639 | | | 3.490 | 0.9298 | 0.565 |
| I can use digital tools without any problems. | 0.637 | | | 3.503 | 0.9083 | 0.573 |
| I can know how to solve the problems I will encounter in the digital environment. | 0.633 | | | 3.444 | 0.8808 | 0.535 |
| I can be a role model for my students in using digital tools. | 0.609 | | | 3.618 | 0.8808 | 0.521 |
| I can understand the working principles of websites. | 0.598 | | | 3.441 | 0.9421 | 0.514 |
| I can perform any action on different operating systems. | 0.587 | | | 3.122 | 1.0253 | 0.488 |
| I can learn the features of digital tools myself. | 0.569 | | | 3.622 | 0.8778 | 0.486 |
| I can install the software which I need myself. | 0.545 | | | 3.109 | 1.1510 | 0.406 |
| I can work with others on the same project online. | 0.537 | | | 3.507 | 0.9817 | 0.414 |
| **Self-efficacy (α=.910)** | | | | | | |
| I can find where to access the right information on the Internet. | | 0.824 | | 4.053 | 0.7603 | 0.701 |
| I can find how to access the correct information on the Internet. | | 0.816 | | 4.023 | 0.7683 | 0.684 |
| I can adapt to new technologies. | | 0.712 | | 3.954 | 0.8813 | 0.645 |
| I can know how digital tools can work. | | 0.703 | | 3.911 | 0.8533 | 0.633 |
| I can confirm the accuracy of the information which I have accessed on the Internet. | | 0.683 | | 3.788 | 0.8568 | 0.528 |
| I can use different digital devices. | | 0.667 | | 3.859 | 0.8422 | 0.546 |
| I can decide when digital tools will work. | | 0.628 | | 3.822 | 0.8412 | 0.594 |
| I can use necessary digital technologies to solve the problem. | | 0.627 | | 3.756 | 0.8363 | 0.516 |
| I am curious about new technologies. | | 0.596 | | 4.115 | 0.8918 | 0.450 |
| I would like to learn new information about digital technologies. | | 0.564 | | 4.128 | 0.8674 | 0.435 |
| I can benefit from expert guidance on new technologies. | | 0.492 | | 3.677 | 0.8756 | 0.301 |
| **Affective (α=.804)** | | | | | | |
| I am concerned about acquiring digital skills. | | | 0.812 | 2.967 | 1.2128 | 0.675 |
| I feel lazy about improving my digital skills. | | | 0.781 | 2.970 | 1.1356 | 0.629 |
| I am afraid of facing too much workload in the event that I demonstrate my digital skills. | | | 0.779 | 3.339 | 1.1662 | 0.614 |
| I do not have enough time to improve my digital skills. | | | 0.722 | 3.171 | 1.1956 | 0.526 |
| Eigenvalues | 11.121 | 2.783 | 1.945 | | | |
| Variance Explained | 38.349 | 9.596 | 6.705 | | | |
| Total Variance | 38.349 | 47.946 | 54.651 | | | |
| **Total (α=.923)** | | | | | | |

teacher candidates' awareness levels. The items in the self-efficacy factor were shown to be connected to the teacher candidates' self-efficacy. Similar to Wang et al. (2013), it has been observed that it contains items related to the psychological processes that affect digital fluency.

The required limit alpha value is expressed as 0.70 and above in order for the internal consistency level of the scale to be considered ideal (Del Rosario & White, 2005). The overall internal consistency coefficient of the scale is $\alpha_{total\ scale}$ = .923 and it is considered reliable. The internal consistency coefficient of the first ($\alpha_{Awareness}$ = .922), second ($\alpha_{Self\text{-}efficacy}$ = .910) and third ($\alpha_{Affective}$ = .804) factors is within the specified intervals and is reliable (Table 6).

Another analysis regarding the reliability of the scale is the testing of the difference between the item average scores of the lower and upper 27% groups, which are formed according to the order of the total scores obtained from the scale from the lowest to the highest (DeVellis, 2016). In this analysis, independent samples t-test was used since the lower and upper groups are independent from each other. It has been observed that there is a significant difference between the digital fluency scale total scores and the lower 27% and upper 27% groups [t(166)= -28.959, p<.001].

The analyses performed revealed a structure in which 29 items were collected under 3 factors. There are 14 items under the “Awareness” factor, 11 items under the “Self-Efficacy” factor and 4 items under the “Affective” factor. It is seen that the Digital Fluency Scale, which was developed as a result of this research conducted with pre-service teachers, exhibits a structure compatible with the literature in terms of the factors it contains in measuring digital fluency (Green, 2005).

### *Confirmatory factor analysis (CFA)*

Data were collected from 274 pre-service teachers via printed form to perform CFA on the 29-item form of the Digital Fluency Scale. Burns et al. (2016) defines less than 100 participants as "small", 100-200 participants as "medium", and more than 200 participants as "large" as acceptable for many models. In this context, it can be seen that the sample determined for CFA is large enough. Data were collected from 274 pre-service teachers to verify the scale of digital fluency. The distribution by departments of pre-service teachers who participated in the data collection process for CFA is shown in Table 7. Table 7 shows the distribution by department and gender of pre-service teachers involved in the CFA data collection process.

The fit indices obtained from the measurement model, tested with the LISREL 9.1 software (Jöreskog et al., 2016). When the fit indices of the model tested with CFA are examined, it is concluded that the Chi-square value ($\chi2$ = 1189.10, df = 371, p <0.001) is moderately significant. It is seen that other fit values for the model ($\chi2$ / df = 3.20, RMSEA = 0.09, SRMR = 0.08, CFI = 0.93, NFI = 0.90, NNFI = 0.92, GFI = 0.78 and AGFI = 0.74) are within acceptable fit value ranges (Beauducel & Wittmann, 2005; Hu & Bentler, 1999; MacCallum & Sehee, 1997; Sun, 2005; Sümer, 2000). It is seen that the values obtained are generally close to ideal and at a medium level. Nevertheless, it has been reported

**Table 7. Distribution of CFA data according to departments**

| Department | Women | | Men | | Total | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| CEIT | 19 | 6.90 | 31 | 11.30 | 50 | 18.20 |
| Mathematics and Science Education | 44 | 16.10 | 11 | 4.00 | 55 | 20.10 |
| Social Sciences and Turkish Education | 58 | 21.20 | 27 | 9.90 | 85 | 31.00 |
| Basic Education | 57 | 20.80 | 27 | 9.90 | 84 | 30.70 |
| **Total** | 178 | 65.00 | 96 | 35.00 | 274 | 100.00 |

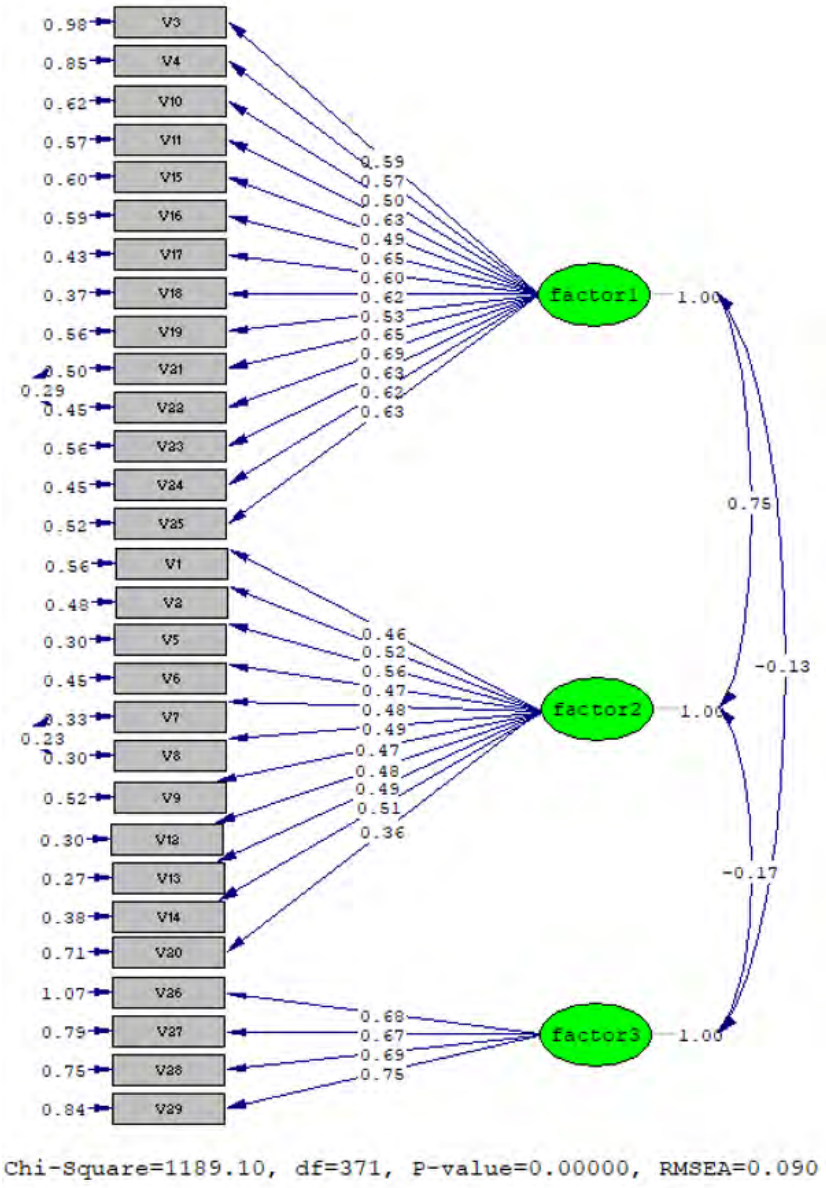


**Figure 2. CFA model of the Digital Fluency Scale**

considering the objective of presenting information and the view that it would be sufficient to present the data with as little correction as possible (Bergqvist et al., 2020). As a result, it can be said that the measurement model revealed by EFA is verified after CFA. The graphic of the measurement model is given in Figure 2.

## Conclusion and recommendations

A valid and reliable scale was developed in this study to assess the digital fluency of pre-service teachers. First of all, an item pool of 47 items was generated using the themes and codes derived from the literature review and the focus group interview. As a result of the EFA and CFA, a scale structure with 3 factors and 29 items was obtained. The factors of the scale include awareness, self-efficacy and affective factors. Although the general internal consistency coefficient of the scale (α=.92) is seen to

be at a high level, it explains 54.65% of the total variance. The awareness factor consists of 14 items, the self-efficacy factor consists of 11 items, and the affective factor consists of 4 items. In order for the internal consistency level of the scale to be considered ideal, the required limit alpha value is expressed as 0.70 and above (Del Rosario & White, 2005). The internal consistency coefficient of the awareness factor (α = .922), self-efficacy factor (α = .910) and affective factor (α = .804) are within the specified ranges and are reliable. High scores from the scale indicate a high level of digital fluency.

The items under the awareness factor express the behaviors of displaying high-level digital literacy knowledge and skills. Especially the ability to abstract the way computer concepts work is considered important. Feeling competent regardless of operating system or digital tool type is one of the important indicators of digital fluency. When the items under the awareness factor are examined, it is seen that there are items similar to the definitions in the literature (Chou & Chiu, 2020; Hsi, 2007; Liu et al., 2018; National Research Council, 1999; Pinho & Lima, 2013; Ross, 2015; Spencer, 2015; Wang et al., 2013). The items under the self-efficacy factor emphasize competence in the focus of knowledge and skills. Knowing how and where to access correct information and being able to confirm this information reveals that digital fluency is not only a technical competence.

Knowing when digital tools will work is seen as an important skill in problem solving in daily life. When the items under the self-efficacy factor are examined, it is seen that it is structured in the direction of the literature (Briggs & Makice, 2011; Chou & Chiu, 2020; Demir & Odabaşı, 2016; Liu et al., 2018; Pinho & Lima, 2013, Ross, 2015; Spencer, 2015). Items under the affective factor include individuals' concerns about acquiring digital skills. The fear of facing too much workload is striking, especially if she demonstrates her digital skills. When the items under the affective factor are examined, it is seen that it is consistent with the literature and that the attitude towards technology is necessary to increase digital fluency (Spante et al., 2018; Wang et al., 2013).

Despite the quality of this original study, it suffers with some minor limitations. The data were collected from pre-service teachers at a state university in Turkey. Since the study was only conducted in Turkey, the results may not be generalizable to other countries, although the possibilities of this difference are quite small.

Practices aimed at improving the digital fluency skills of pre-service teachers can be included in the courses in the curriculum. It is recommended to conduct research on how the foreign language knowledge of pre-service teachers affects their digital fluency. It is recommended that research be carried out on the quality of activities carried out using digital technologies rather than the type of technology used. Pre-service teachers' digital fluency can be increased not only by their ability to use digital tools but also by considering personal factors. At this point, activities to improve digital fluency skills can be organized in which pre-service teachers can have new experiences, take responsibility and realize extroverted experiences by teamwork.

This scale, which was developed to determine the digital fluency of pre-service teachers, can be adapted to different faculty students, parents and education administrators. The digital fluency of the pre-service teachers also affects the digital fluency of the academicians and administrative staff where they study at the faculty where they study. It is aimed to increase the digital fluency of academic and administrative staff working at the faculty by creating comprehensive education programs to improve their digital skills.

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## Appendix A. The Digital Fluency Scale

| | Totally Disagree | Disagree | Partially Agree | Agree | Totally Agree |
|---|---|---|---|---|---|
| **Factor: Awareness** | | | | | |
| I can produce digital content in the quality that I want in an original way. | 1 | 2 | 3 | 4 | 5 |
| I can be a role model in using digital tools. | 1 | 2 | 3 | 4 | 5 |
| I have enough interest to improve my digital skills. | 1 | 2 | 3 | 4 | 5 |
| I have the necessary motivation to develop my digital competencies. | 1 | 2 | 3 | 4 | 5 |
| I can think abstractly in relation to computer concepts. | 1 | 2 | 3 | 4 | 5 |
| I can understand the way search engines generate results. | 1 | 2 | 3 | 4 | 5 |
| I can use digital tools without any problems. | 1 | 2 | 3 | 4 | 5 |
| I can know how to solve the problems I will encounter in the digital environment. | 1 | 2 | 3 | 4 | 5 |
| I can be a role model for my students in using digital tools. | 1 | 2 | 3 | 4 | 5 |
| I can understand the working principles of websites. | 1 | 2 | 3 | 4 | 5 |
| I can perform any action on different operating systems. | 1 | 2 | 3 | 4 | 5 |
| I can learn the features of digital tools myself. | 1 | 2 | 3 | 4 | 5 |
| I can install the software which I need myself. | 1 | 2 | 3 | 4 | 5 |
| I can work with others on the same project online. | 1 | 2 | 3 | 4 | 5 |
| **Factor: Self-efficacy** | | | | | |
| I can find where to access the right information on the Internet. | 1 | 2 | 3 | 4 | 5 |
| I can find how to access the correct information on the Internet. | 1 | 2 | 3 | 4 | 5 |
| I can adapt to new technologies. | 1 | 2 | 3 | 4 | 5 |
| I can know how digital tools can work. | 1 | 2 | 3 | 4 | 5 |
| I can confirm the accuracy of the information which I have accessed on the Internet. | 1 | 2 | 3 | 4 | 5 |
| I can use different digital devices. | 1 | 2 | 3 | 4 | 5 |
| I can decide when digital tools will work. | 1 | 2 | 3 | 4 | 5 |
| I can use necessary digital technologies to solve the problem. | 1 | 2 | 3 | 4 | 5 |
| I am curious about new technologies. | 1 | 2 | 3 | 4 | 5 |
| I would like to learn new information about digital technologies. | 1 | 2 | 3 | 4 | 5 |
| I can benefit from expert guidance on new technologies. | 1 | 2 | 3 | 4 | 5 |
| **Factor: Affective** | | | | | |
| I am concerned about acquiring digital skills. | 1 | 2 | 3 | 4 | 5 |
| I feel lazy about improving my digital skills. | 1 | 2 | 3 | 4 | 5 |
| I am afraid of facing too much workload in the event that I demonstrate my digital skills. | 1 | 2 | 3 | 4 | 5 |
| I do not have enough time to improve my digital skills. | 1 | 2 | 3 | 4 | 5 |

## Appendix B. Basis References of Digital Fluency Scale Draft Items

| Draft Item | Basis Reference |
|---|---|
| I would like to learn new information about digital technologies. | Briggs & Makice, 2011; Focus group interview; Pinho & Lima, 2013 |
| I'm curious about new technologies. | Briggs & Makice, 2011; Focus group interview; Pinho & Lima, 2013 |
| I can edit the favorites in my internet browser. | National Research Council, 1999 |
| I can keep my academic profile (information) on the internet up to date. | Savin-Baden, 2015 |
| I can do my work faster in the digital environment. | Demir & Odabaşı, 2016 |
| I can find the software which I need on the internet. | Spencer, 2015 |
| I can install the software which I need myself. | Spencer, 2015 |
| I can do my computer work without help. | Pinho & Lima, 2013; Spencer, 2015 |
| I can perform any action on different operating systems. | Pinho & Lima, 2013 |
| I can use different digital devices. | Spencer, 2015 |
| I can use necessary digital technologies to solve the problem. | Liu et al., 2018 |
| I can find where to access the right information on the Internet. | Demir & Odabaşı, 2016; Liu et al., 2018; Miller & Bartlett, 2012; Spencer, 2015 |
| I can find how to access the correct information on the internet. | Demir & Odabaşı, 2016; Liu et al., 2018; Miller & Bartlett, 2012; Spencer, 2015 |
| I can confirm the accuracy of the information which I have accessed on the Internet. | Demir & Odabaşı, 2016; Liu et al., 2018; Miller & Bartlett, 2012; Spencer, 2015 |
| I can ensure my personal security in the digital environment. | National Research Council, 1999 |
| I can work with others on the same project online. | National Research Council, 1999; Ross, 2015 |
| I can think abstractly in relation to computer concepts. | Demir & Odabaşı, 2016; National Research Council, 1999 |
| I can design digital media content using digital tools. | Hsi, 2007 |
| I can adapt to the changes in technology in order to gain new knowledge and skills. | Pinho & Lima, 2013 |
| I can decide when digital tools will work. | Demir et al., 2015 |
| I can know how digital tools can work. | Demir et al., 2015 |
| I can reliably achieve the desired results through technology. | Miller & Bartlett, 2012 |
| I can adapt to new technologies. | Pinho & Lima, 2013 |
| I can use up-to-date computer applications. | Spencer, 2015 |
| I can know the basic working principles of digital tools. | Miller & Bartlett, 2012; Pinho & Lima, 2013 |
| I can understand the way search engines generate results. | Miller & Bartlett, 2012; Spencer, 2015 |
| I can understand the working principles of websites. | Miller & Bartlett, 2012; Spencer, 2015 |
| I can evaluate the reliability of the information on the internet. | Demir & Odabaşı, 2016; Miller & Bartlett, 2012 |
| I can flexibly use digital tools for different purposes. | Ross, 2015 |
| I can use digital tools without any problems. | Miller & Bartlett, 2012 |
| I can know how to solve the problems I will encounter in the digital environment. | Liu et al., 2018 |
| I can realize the risks I will face in the digital environment. | Demir & Odabaşı, 2016; Miller & Bartlett, 2012 |
| I can use digital tools effectively in problem solving. | Demir & Odabaşı, 2016; National Research Council, 1999 |
| I can learn the features of digital tools myself. | Pinho & Lima, 2013 |
| I can benefit from expert guidance on new technologies. | Focus group interview; Pinho & Lima, 2013; Ross, 2015 |

| | |
|---|---|
| I can use digital tools effectively in my lessons. | Demir & Odabaşı, 2016; National Research Council, 1999; Focus group interview; Pinho & Lima, 2013 |
| I can be a role model for my students in using digital tools. | Pinho & Lima, 2013 |
| I can be a role model in using digital tools. | Pinho & Lima, 2013 |
| I can produce digital content in the quality that I want in an original way. | Hsi, 2007; Pinho & Lima, 2013 |
| I have the necessary motivation to develop my digital competencies. | Focus group interview |
| I have enough interest to improve my digital skills. | Focus group interview; Wang et al., 2012 |
| I feel lazy about improving my digital skills. | Focus group interview; Wang et al., 2012 |
| I don't have enough time to improve my digital skills. | Focus group interview; Wang et al., 2012 |
| I am concerned about acquiring digital skills. | Kuhn, 2017; Focus group interview |
| I am afraid of facing too much workload in the event that I demonstrate my digital skills. | Focus group interview |
| I can know which technology will work where. | Demir et al., 2015; Liu et al., 2018; Pinho & Lima, 2013 |
| I can know which technology will work when. | Demir et al., 2015 |

## Appendix C. Focus Group Interview Questions

| Number | Question |
|---|---|
| 1 | What does the concept of digital fluency evoke? |
| 2 | How would you define the concept of digital fluency? |
| 3 | What characteristics should an individual have in order to be qualified as a digitally fluent individual in daily life? |
| 4 | What are the problems you face in becoming a digital fluent individual? |

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