International Journal of
Financial Studies

MDPI

Article

Digital Financial Knowledge Scale (DFKS): Insights from a Developing Economy

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Abstract: This work aims to create and validate the digital financial knowledge scale (DFKS). Three studies were carried out, including a focus group, expert validation, pre-testing, and the application of item response theory. From these procedures, two versions of the scale were constructed and validated. An evaluation and classification methodology was proposed. Two versions for measuring digital financial knowledge are presented. The long version is composed of 40 items and the short version has 26 items. Applying the proposed methodology, it is possible to classify the level of digital financial knowledge as low, intermediate, or high. The DFKS can be useful for both financial system agents and governments and researchers, who can use it in different contexts. In the banking sector, identifying the level of digital financial knowledge can reduce risks, as losses suffered by clients due to an uninformed adoption of digital banking services break the relationship of trust and can lead to lower financial inclusion.

Keywords: digital financial capability; digital financial knowledge; mobile banking; psychometric tests; financial literacy; digital literacy; digital financial services

Citation: Vieira, Kelmara Mendes, Taiane Keila Matheis, Eliete dos Reis Lehnhart, and Fernando Oliveira Tavares. 2024. Digital Financial Knowledge Scale (DFKS): Insights from a Developing Economy. *International Journal of Financial Studies* 12: 120. https://doi.org/10.3390/ijfs12040120

Academic Editors: Anna Conte, Marcella Corsi, Zacchia Giulia and Paola Paiardini

Received: 13 November 2024
Revised: 25 November 2024
Accepted: 28 November 2024
Published: 2 December 2024

1. Introduction

Digital technologies are being rapidly integrated into the financial sector, introducing new products, services, and providers. The provision of digital financial services is considered an excellent opportunity to enable access to the financial system, promoting universal financial inclusion (Bayar et al. 2021; GPFI 2016, 2017, 2020; Lyons et al. 2021, 2022; OECD 2017a, 2018), expanding financial well-being (Choung et al. 2023), and contributing to the achievement of the Sustainable Development Goals (Lee et al. 2023; Tay et al. 2022). This evolution directly affects individuals and businesses worldwide and requires public managers to adopt policies aimed at increasing digital financial education, consumer financial protection, and the financial inclusion of citizens (Nnaomah et al. 2024; GPFI 2020; OECD 2018).

At the same time that the application of new digital technologies in the financial sector can generate considerable gains, such as the expansion of access to financial services, faster, more secure, and uninterrupted transactions, and the expansion of supply and competition among financial companies, it can also bring new and amplify old risks (Elsinger et al. 2018; Koskelainen et al. 2023). Risks such as the misuse of unknown products by uninformed consumers, new types of fraud, a lack of security, privacy, and data confidentiality, excessive use of digital profiles to identify potential customers, exclusion of undesirable groups, and rapid access to high-cost credit or essentially speculative products (Asif et al. 2024).

The ability of countries to reduce these types of risks and harness the positive effects of the digitalization of financial services is associated with the expansion of the population's level of digital financial knowledge. However, as the OECD argues, the expansion of digital financial services is not always accompanied by increasing levels of digital and financial literacy (OECD 2017a), which is true even among the younger population (OECD 2017b). Thus, the OECD (2018) proposes that countries develop financial education policies, especially aimed at digital financial services, and regularly evaluate the effectiveness of the adopted programs.

Although there is recognition that digitalization requires new knowledge, behaviors, and skills from consumers there is still no consensus or predominant definition for digital financial literacy (Koskelainen et al. 2023). Several authors define it based on the idea of merging financial literacy with digital literacy. Examples include the following definitions: a person's level of understanding of everything related to financial literacy using digital technology (Rahayu et al. 2022); financial literacy in digital financial technology (Setiawan et al. 2020); and the application of digital literacy and financial literacy to enable the use of digital financial services (FinEquity 2021).

According to Kumar et al. (2023), digital financial literacy refers to an individual's understanding and competence in online financial transactions. This definition includes the ability to use digital tools and platforms to make financial decisions and effectively manage personal finances in the digital realm (Abdallah et al. 2024). An even more comprehensive definition is proposed by the Alliance for Financial Inclusion (AFI 2021), which conceptualizes digital financial literacy as acquiring knowledge, skills, confidence, and competence to safely use digitally delivered financial products and services and make informed financial decisions.

Similarly, there are still no consolidated measures of digital financial knowledge. Measures of financial behavior still prevail in the literature, that is, it is necessary to redefine the measures (Ferilli et al. 2024; Kass-Hanna et al. 2022). Given this context, the objective of this study is to construct and validate the digital financial knowledge scale (DFKS). In this scale, digital financial knowledge represents the knowledge and skills necessary to perform digital financial operations. The scale assesses the level of this knowledge based on the individual's self-perception of their knowledge and skills.

The construction of the DFKS is justified by the lack of a universally accepted measure of digital financial knowledge in the literature. There are already some financial knowledge scales (Bajaj and Kaur 2024; Knoll and Houts 2012, 2019; Vieira et al. 2020). However, to our knowledge, scales for the evaluation of digital financial knowledge have not yet been constructed and validated.

The existence of a valid digital financial knowledge scale is essential. From a governmental perspective, as countries evolve in their financial literacy policies and begin to integrate digital competencies into their adopted strategies, a measure to indicate the level of digital financial knowledge of the population is necessary.

Moreover, the importance of evaluating the results of public policies such as the creation of digital accounts for emergency aid payments and income transfer policies is also highlighted. The creation of such accounts alone expands access to the system (Nnaomah et al. 2024), but the effective financial inclusion of citizens depends on their ability to use it, that is, on their level of digital financial knowledge.

From an academic perspective, the existence of an adequate measure of digital financial knowledge is essential for the advancement of studies on this topic. From the structuring of a scale, the levels of financial knowledge in different countries can be compared, and it will be possible to develop integrated models that assess both the antecedents and the impacts of digital financial knowledge.

For the financial system, knowing the level of digital financial knowledge of the customer can help in the construction of financial applications, guide the development of products, and even assist in the creation of media, educational programs, and training initiatives to improve the proficiency of customers in using the available digital financial

technologies. On the other hand, the implementation of widespread digitalization strategies may not bring financial benefits if people do not accept this change due to a low level of knowledge (Ferilli et al. 2024), highlighting the need for a prior assessment of the level of digital financial knowledge of the client portfolio.

2. Method

The digital financial knowledge scale (DFKS) was constructed from three studies. The first study involved a literature review and a focus group to define the measure and initial construction of the items. The second study included expert evaluation and pre-testing of the scale. The third study applied item response theory to estimate the discrimination and difficulty of the items and identify the anchor items. Finally, based on the results of these studies, two versions of the DFKS and an application methodology are proposed.

In the first study, the focus group sample consisted of five people selected for convenience. Two people are bank employees with extensive experience in customer service, two are researchers in financial literacy, and one is an avid user of financial applications.

For the expert evaluation and pre-test, following the recommendation of DeVellis (2016), five experts were contacted. Three researchers have experience in scale construction and two researchers have experience in behavioral finance. For the pre-test, ten respondents were selected for convenience, as recommended by Boateng et al. (2018). The objective of the pre-test was to ensure the adequacy of the language of the scale items for people with different socioeconomic and demographic profiles.

For the third study, an online survey was designed and conducted in Brazil during the second half of 2023. The sample was gathered using the snowball sampling method. Researchers invited participants by sending emails, WhatsApp messages, and sharing on social media. Each participant was encouraged to forward the survey to their family members and friends. Additionally, the researchers leveraged their academic networks, asking other faculty members to share the survey with their students and colleagues. By the end of the collection period, 775 valid responses were obtained. The research was approved by the ethics committee, and the participants signed the informed consent form.

The majority of respondents were women (51.7%), single individuals (64.5%), and white (70%). The average age was 30 years, with a minimum of 16 and a maximum of 87 years. Regarding income, 8.6% have no income, 20.9% earn up to BRL 1320.00 (USD 264.00), 22.3% between BRL 1320.01 and BRL 2640.00 (USD 264.01–USD 528.00), 13.4% between BRL 2640.01 and BRL 3960.00 (USD 528.01–USD 792.00), 11.4% between BRL 3960.01 and BRL 5280.00 (USD 792.01–USD 1056.00), and 23.6% earn above BRL 5280.00 (USD 1056.01). Regarding educational level, 17.9% studied up to high school at most, and 46.7% of the sample have already completed or are currently attending college.

Among the respondents, 85% have checking accounts with traditional physical banks and 58% with digital banks. For banking services, 65% of respondents visit physical branches, 25% use lottery agencies for transactions, 49% rely on self-service terminals, and 33% utilize 24 h ATMs.

The vast majority (80%) have a checking account. A significant portion (41%) hold savings accounts, the most popular financial product in the country. Another widely used product is the credit card, owned by 80% of respondents. Only 3.5% of respondents do not use PIX, the most popular real-time payment system in Brazil.

With the data from this sample, item response theory was used as a method for the construction of the instrument. Among the various mathematical models available, the unidimensional two-parameter logistic model (MLU2) was chosen, as it is suitable for adjusting polytomous items (with two or more response categories), as is the case with the digital financial knowledge scale. To estimate skills and item parameters, the Bayesian expected a posteriori (EAP) method was used, as suggested by Mislevy and Stocking (1989).

After estimating the parameters, short scale construction was performed. In this work was chosen the methodology proposed by Beaton and Allen (1992), which seeks, for each level of the scale, to identify if there are items whose discriminatory power is around this

level and to use these items to describe what respondents whose skills are close to this level know and can do. For the selection of anchor items, the selection criteria proposed by Beaton and Allen (1992) were adopted, with anchor items formally defined as follows:

Let two consecutive anchor levels be Y and Z with Y < Z. A given item is an anchor for level Z, only if the following three conditions are simultaneously satisfied:

$$P(U = 1 \mid \theta = Z) \geq 0.65$$
$$P(U = 1 \mid \theta = Y) \leq 0.50$$
$$P(U = 1 \mid \theta = Z) - P(U = 1 \mid \theta = Y) \geq 0.30$$

Thus, for an item to be an anchor at a given anchor level of the scale, it needs to be correctly answered by a large proportion of individuals with this skill level and a smaller proportion of individuals with the immediately previous skill level. In addition, the difference between the proportion of individuals with these skill levels who get this item right must be at least 30%. Therefore, anchor items are items that characterize a point or level of the scales to which most individuals at that level get the item right, while a considerable percentage of individuals below the scale get the item wrong. These items are intended to discriminate points on the scale that separate individuals that have certain competencies or skills from those who do not have them.

After conducting the three studies for the construction and validation of the scale, a methodology for applying and classifying the level of digital financial knowledge was proposed, which can be used in both the long and short scales. For the definition of the items, the criteria proposed by Chen and Volpe (1998) were used. The results of the two proposed scales were also compared to identify the degree of similarity of the results, using the chi-square test and Spearman's correlation.

Finally, to present preliminary evidence on the possible differences in digital financial knowledge according to profile and socioeconomic variables, the *t*-test and analysis of variance were used.

3. Digital Financial Knowledge Scale: Definition and Items

The digitalization of financial services requires new skills and an understanding of digital financial risks to allow customers to perform everyday financial actions such as personal money management, budgeting, and other forms of short-term financial planning (Koskelainen et al. 2023). Digital financial services are financial operations that use digital technology. Examples of digital services include the use of electronic money, mobile financial services, online financial services, smart ATMs, and branchless banking, by both banking and non-banking institutions. Digital financial services involve a wide range of monetary transactions, such as deposits, withdrawals, and sending and receiving money, as well as payments, credit, savings, pensions, and insurance (Mahdzan et al. 2022). They may also include non-transactional services, such as accessing personal financial information through digital devices.

Financial knowledge, on the other hand, is a method in which people enhance their understanding of financial concepts and risks, enabling them to develop the skills and confidence necessary to make fundamental and secure decisions (OECD 2017b). It involves basic financial concepts such as numeracy, compound interest, inflation, and risk diversification (Lyons et al. 2021), while knowledge of digital financial products and services captures the basic understanding of digital financial products and services (Morgan et al. 2019).

Thus, the digital financial knowledge scale (DFKS) assesses the level of digital financial knowledge, that is, it identifies the individual's ability to use digital financial services. For the construction of the items that make up the scale, the authors were inspired by different items already proposed in the literature (Table 1).

Table 1. Synthesis of items and dimensions related to digital financial knowledge present in other studies.

Item	Dimension	Authors
I understand how to set up an account on digital financial services platforms. I understand how to conduct a transaction using a digital payment application. I understand how to cancel a transaction on a digital payment app. I understand how to use the digital financial services menu.	Practical know-how	Abdallah et al. (2024)
I am aware of digital payment methods such as Phonepe, GPay, Amazon pay, UPI, and so on. I know about online trading of financial securities. I know about digital lending methods such as peer-to-peer transactions. Insurance products can be purchased online.	Knowledge of digital financial services	Ravikumar et al. (2022)
To use the digital payment application, you must first create an account. I know how to make a transaction through a digital payment application. I know how to cancel a transaction on a digital payment application.	Practical know-how of digital financial services	Respati et al. (2023)
Opens a digital financial service without assistance from anyone. Finds a particular digital financial service menu option without assistance from anyone. Initiates a digital financial transaction without assistance from anyone. Completes a digital financial transaction without assistance from anyone. Corrects financial errors using a digital device without assistance from anyone. Reverses or cancels a transaction using a digital device without assistance from anyone.	Mobile money proficiency	Kass-Hanna et al. (2022)

Regarding the scale items, different Likert-type scales have been used in these studies. For example, Kass-Hanna et al. (2022) used an ease scale and considered individuals who responded "very easy" or "easy" or "neither difficult, nor easy" to have proficiency. Abdallah et al. (2024), Ravikumar et al. (2022), and Respati et al. (2023) used a five-point agreement scale.

For the DFKS, we opted to use a scale with the following alternatives: "Yes", "No", "Never tried", and the following question for all items: "Are you able to perform this activity without the help of another person?".

Thus, considering the definition of the scale, the evidence from the literature, and the choice of response alternatives, the initial version of the scale items was constructed. Subsequently, the focus group, expert validation, and pre-test were conducted, leading to the final version of the items. Table 2 presents the 40 items that make up the DFKS, as well as the procedures that inspired their construction (the literature, focus group, experts) and the classification by knowledge level performed by the focus group.

Table 2. DFKS items.

Item	Inspiration
1. Make credit card purchases.	The Literature
2. Make debit card purchases.	The Literature
3. Perform real-time payment transactions.	Focus Group
4. Check current account balance on digital channels.	The Literature
5. Check account statements on digital channels.	The Literature
6. Pay bills on digital channels.	The Literature
7. Update your registration on digital channels.	The Literature
8. Perform a transfer between accounts in different institutions, electronic funds transfer, on digital channels.	Focus Group
9. Change withdrawal and transfer limits on digital channels.	Focus Group
10. Activate an account on digital channels.	Focus Group
11. Locate payment proof for a bill, transfer, or real-time payment on digital channels.	Focus Group
12. Change the access password on digital channels.	The Literature and Focus Group
13. Activate/deactivate the card for domestic purchases on digital channels.	The Literature
14. Create a virtual credit card on digital channels.	The Literature and
15. Open an account at a digital bank.	Focus Group
16. Register a real-time payment key.	The Literature
17. Withdraw at an ATM terminal.	The Literature
18. Make online purchases via real-time payment.	Focus Group
19. Enroll biometric (fingerprint) access.	Focus Group
20. Unblock the app through self-service.	The Literature
21. Find the service channels (phone, email, WhatsApp) on digital channels.	Focus Group
22. Install a banking app on your mobile phone.	Focus Group
23. Use digital channels without the help of another person.	Focus Group
24. Communicate with the manager through digital channels or WhatsApp.	The Literature
25. Identify the fees charged by the bank/brokerage on digital channels.	The Literature
26. Activate/deactivate the card for international purchases on digital channels.	Focus Group
27. Perform an investment or redemption in investment funds or agribusiness letter of credit on digital channels.	The Literature and Experts
28. Perform an investment or redemption in government bonds on digital channels.	The Literature and Focus Group
29. Perform an investment or redemption in savings on digital channels.	The Literature and Experts
30. Perform an investment or redemption in bank deposit certificates on digital channels.	The Literature and Experts
31. Buy and sell stocks on digital channels.	The Literature
32. Buy and sell foreign currency on digital channels.	The Literature, Focus Group, and Experts
33. Buy and sell derivatives (call/put options, futures market, etc.) on digital channels.	The Literature and Focus Group
34. Simulate financing (car, house, etc.) on digital channels.	The Literature and Focus Group
35. Contract a loan on digital channels.	The Literature and Focus Group
36. Contract insurance on digital channels.	Focus Group
37. Release access to open finance (sharing your data between financial institutions) on digital channels.	The Literature and Focus Group
38. Deposit checks on digital channels.	The Literature and Focus Group
39. Withdraw without a card at the ATM terminal.	Focus Group
40. Generate a code in the app to withdraw without the card.	Focus Group
	Focus Group
	Focus Group
	Focus Group

Note: items 1 to 23 represent basic digital financial knowledge and items 24 to 40 represent advanced financial knowledge according to the classification conducted by the focus group.

4. Construction of the DFKS

The first study for the construction of the scale consisted of a literature review and a focus group. From the literature review, the authors previously constructed the definition of the DFKS and the initial set of items, as described in Section 3. At the beginning of the focus group, a presentation was made with the objective of the focus group, the presentation of the scale definition, and the items. After the presentation, the following question was asked, "Does this item represent an appropriate activity to assess digital financial knowledge?" For most of the items, the five participants answered "yes", validating the initially proposed items as adequate for assessing digital financial knowledge.

However, for some items, although considering them adequate, the participants suggested dividing them into more than one item as follows: (1) items 31, 32, and 33 were originally constructed as a single item, but the focus group participants suggested separating the operations of buying and selling stocks (item 31), foreign currency (item 32), and derivatives (item 33); (2) items 35 and 36 were also originally constructed as a single item and were divided into two, separating the contracting of loans (item 35) from insurance (item 36). The argument raised by the focus group was that these activities would involve distinct procedures in the digital context and therefore should be separated.

The second question was then formulated as follows: what other activities would be necessary to assess digital financial knowledge that should be added as scale items? After a broad discussion with statements from all participants, 16 more items were added to the scale with the consensus of all members. The added items are those identified as "focus group" in the "inspiration" column of Table 2.

Next, the participants were asked to classify each item according to the level of digital financial knowledge, using two levels of knowledge, namely basic and advanced. The results of this stage are presented in the third column of Table 2.

Finally, the participants were invited to analyze whether the proposed definition was consistent with what the set of constructed items proposed to measure. The participants were unanimous about the definition, so the following statement was maintained: "The digital financial knowledge scale assesses the level of digital financial knowledge, that is, it identifies the individual's ability to use digital financial services". Thus, after the focus group, the DFKS definition was maintained and the scale was now measured by a set of 39 items.

For the second study, two convenience samples were used. The first sample of five experts evaluated the instrument according to the degree of item relevance and language adequacy. The second sample, made up of ten individuals with different profiles, was interviewed to assess the adequacy of the language of each item. In the evaluation by the experts, the following changes were suggested: (1) in item 25, the insertion of the word "brokerage" was suggested; (2) and items 27 and 28, originally described as a single item, were separated. Thus, after validation by the experts, the scale consisted of the 40 items described in Table 2.

Concluding the second study, the authors conducted the pre-test interviews. All interviewees had a clear understanding of the items and the instrument's instructions. Thus, at the end of this stage, the content validity and face validity of the scale were confirmed.

For the third study, a Google Forms instrument was developed, containing the scale and the respondent's profile questions. In this stage, a sample of 775 cases was obtained, exceeding the minimum number of 10 respondents per item suggested in the literature (Hair et al. 2019). Initially, a factor analysis was estimated to identify the unidimensionality of the scale. The first factor of the factorial analysis presented a percentage of explained variance of 31.16%, a value well above the minimum of 20% suggested by Reckase (1979) as a criterion for accepting the scale's dimensionality, a necessary condition for applying the MLU2.

With the unidimensionality identified, the MLU2 was estimated to identify the discrimination and difficulty of the items. Table 3 presents the coefficients and standard errors for each item of the DFKS.

Regarding the discrimination power, it is observed that items 2 (make debit card purchases) and 17 (withdraw at an ATM terminal) have the lowest discriminatory power. On the other hand, items 3 (perform real-time payment) and 13 (activate/deactivate the card for domestic purchases) are those with the highest discrimination; they distinguish respondents between those who have digital financial knowledge below the parameter and those with knowledge above the parameter.

Table 3. Coefficients and standard errors of the discrimination and difficulty parameters.

Item	Discrimination		Difficulty	
	Coefficient	Standard Error	Coefficient	Standard Error
1	1.087	0.156	−2.578	0.305
2	1.049	0.174	−3.163	0.432
3	3.472	0.501	−1.824	0.115
4	2.415	0.309	−1.943	0.140
5	2.306	0.285	−1.877	0.136
6	2.524	0.301	−1.617	0.112
7	2.636	0.274	−1.111	0.074
8	1.527	0.158	−1.164	0.103
9	2.591	0.247	−0.772	0.056
10	2.090	0.205	−0.965	0.073
11	2.696	0.321	−1.551	0.103
12	1.902	0.188	−0.983	0.080
13	3.033	0.284	−0.633	0.048
14	2.476	0.232	−0.734	0.056
15	2.240	0.220	−0.991	0.071
16	2.800	0.350	−1.623	0.108
17	1.046	0.133	−1.951	0.217
18	2.480	0.313	−1.852	0.134
19	1.701	0.183	−1.388	0.113
20	1.730	0.171	−0.996	0.085
21	2.531	0.267	−1.210	0.080
22	2.322	0.281	−1.740	0.125
23	2.035	0.228	−1.547	0.116
24	1.172	0.117	−0.577	0.085
25	2.089	0.186	−0.555	0.056
26	2.596	0.218	−0.200	0.044
27	2.436	0.201	0.097	0.046
28	2.914	0.246	0.266	0.044
29	2.080	0.182	−0.283	0.051
30	2.844	0.242	0.123	0.043
31	2.301	0.187	0.436	0.053
32	2.583	0.214	0.716	0.056
33	2.162	0.175	0.672	0.059
34	2.048	0.171	−0.080	0.050
35	1.973	0.167	−0.042	0.051
36	2.579	0.212	0.157	0.046
37	2.623	0.215	0.326	0.047
38	1.892	0.160	0.923	0.072
39	1.357	0.122	0.008	0.065
40	1.662	0.141	0.188	0.058

Regarding the difficulty parameter, it is observed that 10 of the 29 items had negative values. Thus, the lower the values, the lower the difficulty of the item. Therefore, credit and debit card purchases are considered the easiest items of digital financial knowledge. Items 32 (buy and sell foreign currency on digital channels) and 38 (deposit checks on digital channels) are considered items with greater difficulty.

Comparing the results of the difficulty parameter with the classification of the items carried out in the focus group, it is identified that most of the items classified by the experts as advanced knowledge also have higher difficulty coefficients, which confirms and validates the initial classification of the experts.

Next, the anchor items were identified according to the Beaton and Allen (1992) criteria. There are 26 items that meet the three established criteria. Thus, these 26 items, as they are the most important to separate different levels of knowledge, were chosen to form the DFKS-short. The items are identified in Appendix A. Therefore, at the end of the IRT application, it is concluded that the initial 40 items should be maintained in the long scale

(DFKS), as they have adequate levels of discrimination and difficulty, and that 26 of these items should be part of the short scale (DFKS-short).

5. Application and Classification Methodology for the Scales

To measure the level of digital financial knowledge, the researcher must choose one of the two scale options. The choice may depend on criteria such as the number of scales and the size of the instrument to be used in the research, as well as the estimated response time. Both scales can be applied online or in printed questionnaires. The instrument should contain the instructions, the items, and the scale as proposed in Appendix A. For the application of the scale, the completion of three steps is suggested.

Step 1: With the answers obtained in the DFKS questionnaire, code the items according to Table 4.

Table 4. Coding of DFKS and DFKS-short items.

Scale	Quantity of Items	Coding
DFKS	40	Yes = 1; No = 0; Never tried = 0.

Step 2: Obtain the digital financial knowledge level of each *jth* respondent from the percentage of correct responses from the application of one of the following equations:

DFKS equation:

$$DFKS_j = \left(\frac{\sum_{i=1}^{40} Item_i}{40}\right) \times 100$$

DFKSS equation:

$$DFKSS_j = \left(\frac{\sum_{i=1}^{26} Item_i}{26}\right) \times 100$$

where the variables are as follows:

$DFKS_j$ is the digital financial knowledge of individual j using the long scale;

$DFKSS_j$ is the digital financial knowledge of individual j using the short scale;

Item i takes the value 1 if the individual marked "yes" on the questionnaire and the value 0 if they marked "no" or "never tried".

Step 3: Calculate the digital financial knowledge level of the sample from the average of the respondents' responses.

$$DFKS_s = \frac{\sum_{j=1}^{n} DFKS_j}{n} \qquad DFKSS_s = \frac{\sum_{j=1}^{n} DFKSS_j}{n}$$

where the variables are as follows:

$DFKS_s$ is the digital financial knowledge of sample s using the long scale;

$DFKSS_s$ is the digital financial knowledge of sample s using the short scale;

$DFKS_j$ is the digital financial knowledge of individual j using the long scale;

$DFKSS_j$ is the digital financial knowledge of individual j using the short scale;

n is the number of respondents.

Step 4: Classify the respondent's or sample's level of knowledge using Table 5.

Table 5. Coding of DFKS and DFKS-short items.

Digital Financial Knowledge Level	Percentage of Hits [1]	Items with "yes"		Values
		DFKS	DFKS-Short	DFKS or DFKS-Short
Low	Up to 60%	Up to 24	Up to 16	DFKS < 60.00
Intermediate	60% to 80%	25 to 31	17 to 21	60.00 ≤ DFKS < 80.00
High	Above 80%	32 to 40	22 to 26	DFKS ≥ 80.00

Note: [1] percentage of correct answers established, as suggested by Chen and Volpe (1998).

6. Comparison Between the Scales

In this step, the sample's level of knowledge was initially identified for each of the DFKS items. Table 6 presents the results.

Table 6. Percentage of interviewees who answered "yes" to the DFKS items.

	Item	Percentage of "Yes"
1	Make credit card purchases.	91.87%
2	Make debit card purchases.	94.84%
3	Perform real-time payment transactions.	95.61%
4	Check current account balance on digital channels.	94.84%
5	Check account statements on digital channels.	94.06%
6	Pay bills on digital channels.	92.26%
7	Update your registration on digital channels.	84.90%
8	Perform a transfer between accounts in different institutions, eletronic funds transfer, on digital channels.	79.87%
9	Change withdrawal and transfer limits on digital channels.	76.65%
10	Activate an account on digital channels.	79.48%
11	Locate payment proof for a bill, transfer, or real-time payment on digital channels.	92.00%
12	Change the access password on digital channels.	78.84%
13	Activate/deactivate the card for domestic purchases on digital channels.	73.68%
14	Create a virtual credit card on digital channels.	75.23%
15	Open an account at a digital bank.	80.77%
16	Register a real-time payment key.	93.03%
17	Withdraw at an ATM terminal.	85.55%
18	Make online purchases via real-time payment.	94.32%
19	Enroll biometric (fingerprint) access.	85.16%
20	Unblock the app through self-service.	78.06%
21	Find the service channels (phone, email, WhatsApp) on digital channels.	86.45%
22	Install a banking app on your mobile phone.	92.90%
23	Use digital channels without the help of another person.	89.55%
24	Communicate with the manager through digital channels or WhatsApp.	64.65%
25	Identify the fees charged by the bank/brokerage on digital channels.	68.77%
26	Activate/deactivate the card for international purchases on digital channels.	58.32%
27	Perform an investment or redemption in investment funds or agribusiness letter of credit on digital channels.	48.13%
28	Perform an investment or redemption in government bonds on digital channels.	41.81%
29	Perform an investment or redemption in savings on digital channels.	60.52%
30	Perform an investment or redemption in bank deposit certificates on digital channels.	46.84%
31	Buy and sell stocks on digital channels.	37.55%
32	Buy and sell foreign currency on digital channels.	28.90%
33	Buy and sell derivatives (call/put options, futures market, etc.) on digital channels.	31.35%
34	Simulate financing (car, house, etc.) on digital channels.	54.06%
35	Contract a loan on digital channels.	52.90%
36	Contract insurance on digital channels.	45.94%
37	Release access to open finance (sharing your data between financial institutions) on digital channels.	40.26%
38	Deposit checks on digital channels.	26.45%
39	Withdraw without a card at the ATM terminal.	51.48%
40	Generate a code in the app to withdraw without the card.	46.32%

The high percentages for activities like purchases made with debit and credit cards, as well as the widespread use of PIX (a real-time payment system), align with the current banking landscape in the country. Brazil has 206,184,949 active credit cards—surpassing the nation's population. PIX has become the most popular payment and transfer method in the country, with over 169 million users and thousands of daily transactions (Central Bank of Brazil 2024).

The items with the highest percentages of "yes" responses among the respondents were those related to basic activities generally performed with high frequency, such as

making purchases with credit and debit cards, making online purchases, bill payments, and real-time payment transactions, and checking balances and statements. On the other hand, the majority are unable to perform activities such as depositing checks through digital channels or buying and selling stocks, derivatives, and foreign currencies without the assistance of others.

Another point to highlight in Table 6 is the convergence between the classification of activities as basic and advanced and the results. In general, the first 23 items that were classified by the focus group members as basic were also the ones with the highest percentages of respondents considering themselves capable of performing the activity, whereas the items classified as advanced (24 to 40) have lower "yes" response rates, meaning that the majority of respondents do not consider themselves capable of performing the advanced digital financial knowledge items.

These results are also consistent with those observed in the application of item response theory, as the items classified by the focus group also generally presented lower difficulty coefficients. Therefore, the evidence confirms the appropriateness of the item classification performed by the experts and suggests that such classification can be used in future research.

Regarding the digital financial knowledge level of the sample, the application of the classification proposed in Table 5 identified that 31.1% of the respondents have low digital financial knowledge, 32.1% intermediate, and 36.8% high when applying the long scale. If the short scale was used, the percentages would be 35.1%, 33.7%, and 31.2%. Therefore, the scales presented a quite homogeneous distribution among the levels of digital financial knowledge.

Finally, with the objective of evaluating and comparing the results between the two scales, Spearman's correlation and the chi-square test were used. Table 7 presents the results.

Table 7. Comparison of DFKS and DFKS-short scale results.

Scale/Level		DFKS			
		Basic	**Intermediate**	**Advanced**	**Total**
DFKS-Short	Basic	96.3%	16.1%		35.1%
	Intermediate	3.7%	81.5%	17.2%	33.7%
	Advanced		2.4%	82.8%	31.2%
	Total	100.0%	100.0%	100.0%	100.0%
Pearson's Chi-square: 1023.39 (0.000)					
Likelihood Ratio: 1088.71 (0.000)					
Spearman's Correlation Coefficient: 0.908 (0.000)					

The results of the chi-square test and Spearman's correlation indicate that there is a very high association between the classifications of the two scales. Overall, for 86.6% of the respondents, the classification for the long scale is the same as the short scale. At the basic level, the convergence of results is 96.3% of the cases, and at the higher levels, it is over 80%. Therefore, it can be concluded that the short scale is a very close measure to the long scale for measuring the level of digital financial knowledge. Thus, the user can choose the DFKS version that best suits their study.

7. DFKS: Difference Tests

With the objective of presenting evidence of differences in digital financial knowledge based on profile and socioeconomic variables, the *t*-test and analysis of variance were applied. Table 8 presents the results.

Table 8. Mean difference tests for the DFKS according to the variables of gender, age, marital status, and income.

Variable	Categories	DFKS		Homogeneity Test	Difference Test	
		Mean	Standard Deviation	Sig	Value	Sig
Gender	Female	66.89	20.07	0.012	−4.612	0.000
	Male	74.11	22.78			
Age	16 to 25	70.69	20.18	0.000	7.13	0.000
	26 to 35	76.30	19.07			
	36 to 45	67.02	23.62			
	46 to 55	65.96	22.23			
	56 to 87	57.11	31.22			
Marital Status	Single	70.94	20.06	0.000	1.075	0.365
	Married or stable relationship	68.50	24.95			
	Separated or divorced	66.36	24.84			
	Other	64.81	30.36			
Income	No income	68.02	22.45	0.388	7.972	0.000
	Up to BRL 1320.00.	62.80	20.31			
	Between BRL 1320.01 and BRL 2640.00.	68.70	22.23			
	Between BRL 2640.01 and BRL 3960.00.	70.26	24.28			
	Between BRL 3960.01 and BRL 5280.00.	70.31	21.43			
	Above BRL 5280.01	77.34	20.48			

Note: gender—homoscedastic *t*-test; age and marital status—Welch's robust ANOVA; income—ANOVA.

The results demonstrate significant differences for gender, age, and income. For gender, women have on average lower digital financial knowledge than men. Although there is a lack of specific previous evidence on digital financial knowledge, these results are consistent with the broad evidence that women have lower levels of financial literacy (Karakurum-Ozdemir et al. 2019; Tinghög et al. 2021) and digital literacy (Long et al. 2023), as well as lower levels of financial knowledge (Aristei and Gallo 2023; Chen and Garand 2018).

For age, the general observation is that younger individuals have higher average percentages than older ones. According to the Games–Howell post hoc test, young adults (26 to 35 years old) have on average higher digital financial knowledge than all other age groups. On the other hand, the oldest (56 to 87 years old) have significantly lower percentages than the two younger age categories (16 to 35 years old). Again, the results are in line with the evidence that young, adult, and older individuals have different levels of financial literacy (Finke et al. 2017) and digital literacy (Long et al. 2023).

Regarding income, Setiawan et al. (2020) and Rahayu et al. (2022) found evidence that digital financial literacy is higher in individuals with higher income levels. Our results are consistent with this evidence, as the average DFKS score is higher in the higher-income classes. The Tukey post hoc test indicated that the average knowledge of the highest income class is significantly higher than the three lower-income classes.

Therefore, these results suggest that, as in other behavioral financial phenomena, such as financial inclusion, financial literacy, and financial well-being, significant differences may also be obtained regarding digital financial knowledge. Thus, both the DFKS and the DKFS-short may be useful for identifying the most vulnerable groups on which efforts should be focused for digital financial education.

8. Concluding Remarks

In the current technological scenario, as the offer of digital financial products and services grows, customers increasingly depend on digital channels instead of accessing physical branches (Mogaji 2023). Thus, consumers are increasingly responsible for their

financial decisions (Yadav and Banerji 2023) and are forced to adapt to new technologies to avoid being excluded from the financial system. This change brings many advantages, such as facilitating access to existing and novel financial products and services and making it possible to tailor products and lower the costs of services. However, it also increases risks such as the potential misuse and fraud of digital services, issues of data confidentiality, and digital profiling (Koskelainen et al. 2023).

Thus, one of the great challenges for both governments and financial system agents is to be able to identify the extent to which citizens can or cannot deal with these changes, that is, the assessment of the level of digital financial knowledge. Therefore, in the absence of a consolidated measure in the literature, this work presented evidence of the validity of the digital financial knowledge scale (DFKS).

Two versions of the DFKS were constructed, the first with 40 items and the second with 26 items. The comparisons indicate that both present similar results, giving security to the potential user of the scale to choose the version that is most appropriate to the evaluation context.

The DFKS is a simple scale that can be used in different contexts. From the perspective of financial agents, the scale can be useful both to identify the level of financial knowledge of current and potential customers and to identify, based on the evaluation of the items, which knowledge/skills are not yet mastered by customers and could be improved through different strategies such as nudges, online courses, and improvements in apps, among others. Identifying the level of digital financial knowledge is also a useful tool for risk reduction. Customers with low levels of digital financial knowledge are a source of reputational and operational risks for credit institutions because the misuse of innovative and digital financial services could lead customers towards losses and claims requests (Ferilli et al. 2024). Losses suffered by customers due to an uninformed adoption of digital banking services break the trust relationship typical of banking activity and leads to lower financial inclusion (Ammari et al. 2023).

From an academic perspective, the existence of a robust model for the assessment of digital financial knowledge is fundamental for the evolution of research on this topic. In this sense, the DFKS can be used (1) in studies aimed at evaluating digital financial knowledge in isolation or together with other measures of digital financial behavior, attitude, trust, and capacity; (2) in experimental and quasi-experimental studies, as a measure of evaluation of treatments such as courses, nudges, etc.; (3) in longitudinal studies aimed at monitoring the evolution of the level of digital financial knowledge of the general population or specific groups; and (4) in causal studies, as an antecedent of financial decisions, such as the choice and purchase of financial products and services and also as an influencer of other behaviors such as compulsive online shopping, the assumption of digital financial risks, investments in different financial products, etc. It can also be evaluated as a consequence of other digital phenomena such as the use of digital apps, in general, or participation in social media and YouTuber channels. (5) The DFKS can also be used in bidirectionality studies to deepen the understanding of the relationship between product usage and digital financial knowledge. (6) Considering the sustainable development goals, the contribution of digital financial knowledge to financial inclusion, financial education, and financial well-being in different countries and cultures can also be analyzed.

Additionally, international organizations suggest that governments adopt policies and strategies for digital financial education. Thus, it is essential that governments make successive evaluations of the results of the implementation of such strategies, and the DFKS is a simple alternative both for evaluating the results of the implemented actions and for identifying the most vulnerable groups that require differentiated strategies.

Despite efforts to build a comprehensive study, the DFKS still needs cross-cultural validation. Another limitation is the failure to perform predictive validity and concurrent validity tests. Additionally, the research is subject to biases commonly associated with surveys, such as socially desirable responses, as well as selection bias and other limitations related to data collection through the snowball sampling method.

Author Contributions: Conceptualization, K.M.V., T.K.M., E.d.R.L. and F.O.T.; methodology, K.M.V. and T.K.M.; software, K.M.V. and T.K.M.; formal analysis, K.M.V., T.K.M., E.d.R.L. and F.O.T.; investigation, K.M.V., T.K.M. and E.d.R.L.; data curation, K.M.V. and E.d.R.L.; writing—original draft preparation, K.M.V., T.K.M., E.d.R.L. and F.O.T.; writing—review and editing, K.M.V. and T.K.M.; project administration, K.M.V.; funding acquisition, K.M.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Council for Scientific and Technological Development (CNPq) grant number 308953/2022-3.

Institutional Review Board Statement: This study was approved by the Research Ethics Committee of the Federal University of Santa Maria (approval number 6,295,374) on 12 September 2023.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data presented in the study are openly available in Mendeley Data [DOI: 10.17632/79m467kjk5.1].

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Instructions for respondents: This questionnaire aims to assess the level of digital financial knowledge. For each of the following items, you should consider whether you are able to perform the activity without the help of another person and choose between the alternatives "Yes", "No", or "Never Tried".

Scale to be used: If the long scale is used, present the 40 items in the table. In the case of using the short scale, use only the 26 items marked in the DFKS-Short column.

Digital Finance Knowledge Scale (DFKS)	DFKS-Short	Yes	No	Never Tried
Do you know how to perform this activity without the help of another person?				
1 Make credit card purchases.	☒			
2 Make debit card purchases.	☒			
3 Perform real-time payment transactions.				
4 Check current account balance on digital channels.				
5 Check account statements on digital channels.				
6 Pay bills on digital channels.				
7 Update your registration on digital channels.	☒			
8 Perform a transfer between accounts in different institutions, eletronic funds transfer, on digital channels.	☒			
9 Change withdrawal and transfer limits on digital channels.				
10 Activate an account on digital channels.				
11 Locate payment proof for a bill, transfer, or real-time payment on digital channels.				

Digital Finance Knowledge Scale (DFKS)	DFKS-Short	Yes	No	Never Tried
Do you know how to perform this activity without the help of another person?				
12 Change the access password on digital channels.				
13 Activate/deactivate the card for domestic purchases on digital channels.				
14 Create a virtual credit card on digital channels.				
15 Open an account at a digital bank.				
16 Register a real-time payment key.				
17 Withdraw at an ATM terminal.				
18 Make online purchases via real-time payment.				
19 Enroll biometric (fingerprint) access.				
20 Unblock the app through self-service.				
21 Find the service channels (phone, email, WhatsApp) on digital channels.				
22 Install a banking app on your mobile phone.				
23 Use digital channels without the help of another person.				
24 Communicate with the manager through digital channels or WhatsApp.				
25 Identify the fees charged by the bank/brokerage on digital channels.				
26 Activate/deactivate the card for international purchases on digital channels.				
27 Perform an investment or redemption in investment funds or agribusiness letter of credit on digital channels.				
28 Perform an investment or redemption in government bonds on digital channels.				
29 Perform an investment or redemption in savings on digital channels.				
30 Perform an investment or redemption in bank deposit certificates on digital channels.				
31 Buy and sell stocks on digital channels.				

Digital Finance Knowledge Scale (DFKS)	DFKS-Short	Yes	No	Never Tried
Do you know how to perform this activity without the help of another person?				
32 Buy and sell foreign currency on digital channels.	✓			
33 Buy and sell derivatives (call/put options, futures market, etc.) on digital channels.	✓			
34 Simulate financing (car, house, etc.) on digital channels.	✗			
35 Contract a loan on digital channels.	✗			
36 Contract insurance on digital channels.	✓			
37 Release access to open finance (sharing your data between financial institutions) on digital channels.	✓			
38 Deposit checks on digital channels.	✗			
39 Withdraw without a card at the ATM terminal.	✗			
40 Generate a code in the app to withdraw without the card.	✓			

Legend: ✓ DFKS-short items; ✗ Exclusive items of the DFKS long scale.

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