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Psychometric analysis of a test to assess the digital competence of compulsory education students

Análisis psicométrico de una prueba para evaluar la competencia digital de estudiantes de Educación Obligatoria

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Abstract

Valid and reliable information-gathering tools are necessary if research on digital competence is to provide valuable information that is able to guide education policies on the development of digital competence and the integration of information and communication technologies (ICT) into the educational systems of different countries.

The aim of the present work is to validate a test that assesses the digital competence of students undertaking compulsory education (ECODIES). The test examined the areas of general knowledge, ability and attitude. The present research was based on the Development and Understanding of Digital Competence in Europe Framework (DigComp). The tool was designed by a university research team and was administered to a sample of 771 students. The ease/difficulty index was applied to the test and its overall and dimensional validity and reliability were analyzed. It was concluded that ECODIES is an original and novel test. It has good psychometric properties that make it a reliable and valid instrument for directly measuring digital competence in relation to real situations and problem solving.

Keywords: assessment; educational technology, basic education, psychometry.

Resumen

Para que las investigaciones sobre la competencia digital puedan aportar información valiosa que contribuya a guiar las políticas educativas de desarrollo de la misma y de integración de las Tecnologías de la Información y la Comunicación en los sistemas educativos de los países, es necesario contar con instrumentos de recogida de información válidos y fiables.

El objetivo del presente trabajo es el de validar una prueba para evaluar la competencia digital en estudiantes de Educación Obligatoria, en los ámbitos de conocimiento, capacidad y actitud; teniendo como base el Marco para el Desarrollo y la Comprensión de la Competencia Digital en Europa. Este instrumento, diseñado por un equipo de investigación universitario, fue aplicado a una muestra de 771 estudiantes. Se analiza el índice de facilidad/dificultad de la prueba y por dimensiones, así como la validez y la fiabilidad. Se concluye que la prueba es original, novedosa y presenta unas buenas propiedades psicométricas que permiten calificarla como un instrumento fiable y válido para medir la competencia digital en todas sus dimensiones, de manera directa, mediante la reflexión sobre situaciones reales y la resolución de problemas.

Palabras clave: evaluación; tecnología de la educación; educación básica; psicometría.

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In recent years, information and communication technology (hereafter ICT) has brought about a revolution in the entire social spectrum, especially in the way in which we communicate and obtain information (Lores Gómez et al, 2019). Internet-based mobile devices have changed the way in which people learn. Even though all stages of the education system have gradually fostered the inclusion of technological innovations, education has not yet exploited the potential that technology has in this field (Hea et al, 2020; Larionova et al., 2018). Further, it is currently facing the challenge of using ICT in a way that students can develop the knowledge, skills and attitudes required to access information, as a source of learning in a globalized world (Alvarado Martínez, 2020). Technology has become part of students' lives and is, therefore, essential inside and outside of the classroom (Valverde Crespo et al, 2018). Hence, digital competence is one of the most important and demanded capacities in societies across the world and its assessment is crucial for steering policies and programs aimed at its development.

This study analyses the psychometric properties of a test to assess digital competence in compulsory education students (ECODIES).

Digital competence assessment

Competence refers to complex 'know-how' that encompasses a complementary set of knowledge, skills and attitudes which enable responsible and efficient professional practice, in this way conveying expertise (knowledge), 'know-how' (skills) and adequate behavior (attitudes) when engaging in any action (Armengol et al., 2011). In this way, people develop a broad range of capacities which allow them to learn and unlearn throughout their lives, in this way adapting to changing situations (Martínez et al., 2012).

In the European context, digital competence is one of the eight key competences for lifelong learning. It is defined as:

> The safe, critical and responsible use of, and engagement with, digital technologies for learning, work and participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property affairs, problem solving and critical thinking (European Union, 2018, p. 9).

Competence assessment involves defining both the achievements and room for improvement of an individual in connection with a task. It considers performance criteria and indicators regarding task completion and problem solving, and considers knowledge, 'know-how' and knowing 'how to be' (Tobón et al., 2010).

To ensure quality in competence-based assessment processes, it is necessary to consider a series of criteria (Valverde Berrocoso et al., 2012):

- Authenticity. Assessment tasks should enable students to demonstrate the same type of competences that they would need in a real-life scenario.
- Cognitive complexity. The knowledge, skills and attitudes to be assessed must be consistent with the demanded knowledge, skills and attitudes.
- Impartiality. All activities must be adjusted to the student's educational level and be set within their cultural context.
- Significance. Assessment should allow students to become involved in the resolution of significant activities, tasks or problems that provide interesting educational experiences.
- Direct interpretation. Researchers should be able to analyze and clearly explain the results of the assessment.
- Educational consequences. Outcomes should be used to orient and guide learning.

When assessing digital competence, it is necessary to distinguish between two types of assessment processes according to the instrument used: (a) those based on subjects' self-assessment in relation to different aspects of digital competence (see, for example: Agudo

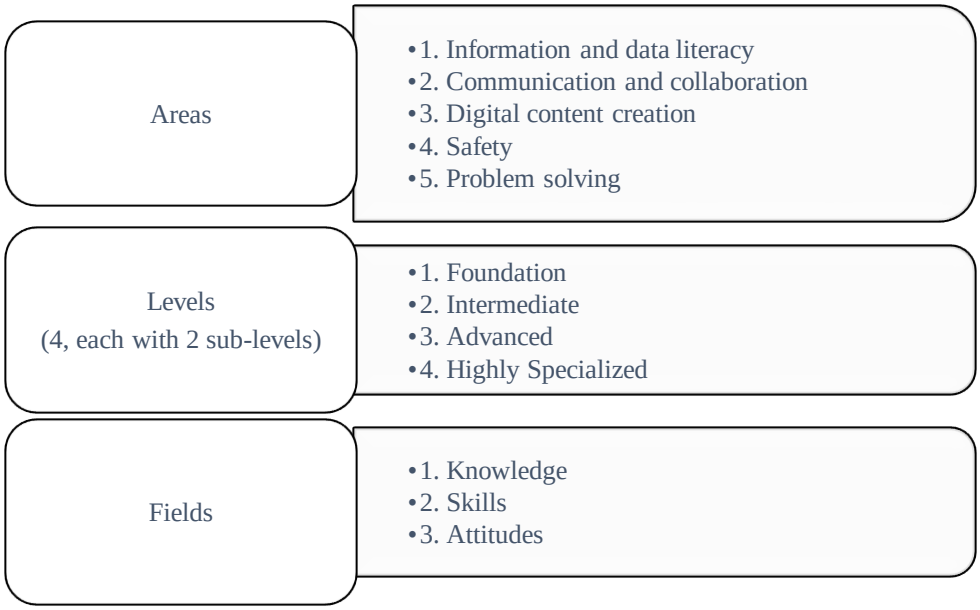
et al., 2020; Basantes-Andrade et al., 2020; Bonnes et al., 2020; Cabezas-González & Casillas-Martín, 2018; Hea et al., 2020) and; (b) those that are focused on assessment of the actual level of digital competence (see, for example: García-Valcárcel et al., 2019; García-Valcárcel et al, 2020; Frailon et al., 2013). In the case of the former, which is the most widely used method, assessment is a self-assessment process based on personal perceptions. However, this mode of assessment is seriously biased due to the subjective nature of participants' responses. Thus, reliable conclusions cannot be drawn beyond those that the assessed individual claims to know or know how to do (González-Segura et al., 2018). In the case of the latter, this pertains to a direct measurement that observes the completion of tasks, activities or problem solving. It is, therefore, a more adequate and reliable way to measure digital competence because

> competence assessment requires focusing on actions and assessing students' performance during the process of addressing specific situations in a variety of contexts… To decide whether a student has developed a certain competence, it is necessary to assess his/her performance, ideally when faced with a challenge that requires the use of the competence under consideration. (González-Segura et al, 2018, pp. 2-3).

Reference framework for assessment of digital competence

Digital competence assessment is a topic of increasing interest in the area of educational research. Different models pertaining to standards and indicators have emerged over the years in order to develop and assess this competence, both in the field of teaching and in the field of learning. Examples include the TPACK model (Mishra & Koehler, 2006), Krumsvik model (Krumsvik, 2011), DigCompEdu (Punie, 2017) and *Standards for Students, a Practical Guide for Learning with Technology* (ISTE, 2016), amongst others. This study is based on the European Digital Competence Framework (DigComp).

Figure 1. Structure of DigComp 2.1 and its dimensions of digital competence



In August 2013, the European Commission published the Framework for Developing and Understanding Digital Competence in Europe (DigComp 1.0) (Ferrari, 2013). This model arranged the dimensions of digital competence into five areas, three levels and three fields. In

June 2016, it was updated by the European Digital Competence Framework for Citizens (DigComp 2.0) (Vuorikari et al., 2016), which maintained the same structure of its predecessor but updated the terminology, concepts and descriptors of digital competence. DigComp 2.0 was further developed in 2017, leading to DigComp 2.1. (Carretero et al., 2017), whose main change involved increasing the initial three proficiency levels to eight, following Bloom's taxonomy and inspired by the structure and vocabulary of the European Qualification Framework (EQF) (figure 1). This new framework includes a total of 21 digital competences, as gathered in table 1.

Table 1. DigComp 2.1. digital competences

Area	Competences
Information and data literacy	1. Browsing, searching and filtering data, information and digital content 2. Evaluating data, information and digital content 3. Managing data, information and digital content
Online communication and collaboration	4. Interacting through digital technologies 5. Sharing through digital technologies 6. Engaging in citizenship through digital technologies 7. Collaborating through digital technologies 8. Netiquette 9. Managing digital identity
Digital content creation	10. Developing digital content 11. Integrating and re-elaborating digital content 12. Copyright and licenses 13. Programming
Safety	14. Protecting devices 15. Protecting personal data and privacy 16. Protecting health and well-being 17. Protecting the environment
Problem solving	18. Solving technical problems 19. Identifying needs and technological responses 20. Creatively using digital technologies 21. Identifying digital competence gaps

Source: Carretero et al. (2017)

Method

The method followed in order to carry out psychometric analysis of a test to assess the digital competence of compulsory education students is described below.

Aims

The main purpose of the present study is to validate a test, based on the Framework for Developing and Understanding Digital Competence in Europe (DigComp), for assessing digital competence in compulsory education students (ECODIES). This tool was designed to assess knowledge, abilities and attitudes.

This general purpose comprised the following specific objectives:

1. To identify levels of various areas of digital competence in compulsory education students.
2. To measure reliability and validity of the tool designed to measure digital competence.
3. To verify the test's ease/difficulty of use for each of the competence areas and fields.
4. To conduct an exploratory factor analysis of the main factors in order to verify construct validity and internal consistency, and uncover the number of

test factors underlying each of the different competence areas.

Sample

Stratified random sampling (Otzen & Manterola, 2017) was used with a population of 816 students in the 12-14 age range, of which 771 completed the entire test. The students were enrolled at 23 education centers in the autonomous community of Castile and Leon (Spain). The sample was balanced with regards to gender and in terms of educational stage, although to a lesser extent in the case of the latter as the majority of students were in the last year of primary education (table 2).

Table 2. Sample distribution

Areas	N	Stage				Gender			
		Year 6 primary education		Year 1 compulsory secondary education		Females		Males	
		N	%	N	%	N	%	N	%
A1	816	676	82.8	140	17.2	420	51.5	396	48.5
A2	807	668	82.8	139	17.2	415	51.4	392	48.6
A3	787	657	83.5	130	16.5	399	50.7	388	49.3
A4	771	655	85	116	15	389	50.5	382	49.5
A5	772	653	84.6	119	15.4	391	50.6	381	49.4

Note: A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving

Test characteristics and data collection

The researchers designed the test following the DigComp 1.0 model (Ferrari, 2013). Indicators of the five competence areas pertaining to digital competence were elaborated (A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving) and adapted to the study population. They were organized according to three difficulty levels (basic, intermediate and advanced) and three developmental fields (knowledge, abilities and attitudes). These indicators can be found in the *Indicator Model for Assessing Student Digital Competence in Basic Education, Taking into Account the DigComp Model (INCODIES)* (García-Valcárcel et al., 2019). Content of the model was validated by expert judges. Each competence area was considered by a total of 18-20 experts in the design of assessment indicators and digital competence, who were also active professionals in different educational areas (compulsory education, university, education management). These experts assessed the importance, pertinence and clarity of the different indicators by means of an online questionnaire based on a 4-point Likert scale (4 – a lot, 3 – quite a bit, 2 – a little, 1-not at all).

A question pool was developed for each of the five areas using this model of indicators considering criteria for the preparation and implementation of the information gathering instrument (McMillan & Schumacher, 2010). This battery of items was the refined following review by experts and researchers. This review led to the first version of the assessment test. This was given to a pilot sample of 288 compulsory secondary education students. The information obtained was used to estimate the difficulty of responded to knowledge and ability questions, as well as the reliability of items pertaining to attitude. These results were used to draw up the final version of the *test to assess students' digital competence*, using the *DIGCOMP model* as a reference *(ECODIES)* (available at https://gredos.usal.es/handle/10366/139397). Its item structure is shown in table 3.

Table 3. Structure of the ECODIES test

Area	Number of items per competence field (final version)			Number of items per competence level (pilot test)		
	Knowledge	**Ability**	**Attitude**	**Basic**	**Intermediate**	**Advanced**
A1	6	6	6	2	6	4
A2	8	10	6	7	8	3
A3	5	11	6	2	8	6
A4	6	10	6	6	6	4
A5	7	9	6	3	9	4
TOTAL ITEMS 108	32	46	30	20	37	21

Note:
- A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving
- The items indicated for each area and field have different proficiency levels

The group of items pertaining to attitudes was assessed using a five-point Likert scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree), with each area consisting of six statements. The final scale was made up of a total of 30 items (available at https://gredos.usal.es/handle/10366/139397).
The test was implemented online through a web platform designed *ad hoc* (https://www.ECODIES.es/) with the purpose of increasing student response. Permission to carry out the research was given by the authorities of the relevant educational administration and the ethical committee of the University of Salamanca.

Before conducting any assessment, packs were sent to the chosen education centers requesting the participation of 6th year primary education and/or 1st year compulsory secondary education students. All students collaborated voluntarily and permission was obtained from both parents/legal guardian and the children themselves (following protocols drawn up by the researchers). All testing was completed during teaching hours.

Data analysis

Different analyses were performed:

1. Basic descriptive analysis was conducted of all of the areas of the fields of knowledge, ability and attitudes in order to acquire a general overview of the tool and carry out a comprehensive review of the entire test.
2. Exploratory factor analysis (EFA) examined construct validity and internal consistency, and uncovered the number of factors underlying examination of each of the areas.
3. Principal component analysis with varimax rotation.
4. Estimation of the difficulty/ease index based on the number of correct answers (%) in relation to all areas, competences and the different fields (knowledge, ability and attitudes).
5. Test reliability was examined using Cronbach alpha, ordinal alpha and Armor Theta statistics. The latter two were used due to the test's dichotomous nature.

All analyses were conducted using SPSS v24 statistical software and Corrector 1.2 software developed by Professor Gaviria of the Department of Research Methods of the Complutense University of Madrid. This software works as an MS-Excel add-in and allows analysis of objective tests and Likert-type scales, providing information for each item and the instrument as a whole. The Excel worksheet (Domínguez Lara, 2018) is based on a matrix of tetrachoric correlations and was also used to estimate reliability of the dichotomous items.

Results

Below are the main outcomes obtained following analysis of collected data.

Basic descriptive statistics

The following descriptive statistics show the final test scores given for each of its five areas. Values are reported as the sum of scores obtained on the knowledge-ability test (table 4).

In order to calculate means, a variable was created which summed scores pertaining to the areas of knowledge and ability for each competence area. For each item, correct responses were categorized as 1 and incorrect responses as 0. The final scores achieved are the product of the sum of correct responses for each of the items that make up each of the different areas.

With regards to items pertaining to attitudes, each response was categorized according to a five-point scale: strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). The final score was calculated by summing values pertaining to responses given to the six attitude items. Final scores ranged between 0 and 30. Scores obtained in relation to the attitudes scale are provided separately in table 5.

Table 4. Descriptive statistics resulting from the ECODIES test in relation to the knowledge-ability field

Areas (max. score)	N	Min	Max	χ	$\bar{x}$	Skewness		Kurtosis	
						Y_1	SE	g2	SE
A1 (max 12)	816	0	11	5.32	2.04	0.076	0.086	-0.376	0.171
A2 (max 18)	807	0	17	9.66	2.98	-0.359	0.086	-0.102	0.172
A3 (max 16)	787	0	13	6.42	2.35	0.184	0.087	-0.271	0.174
A4 (max 16)	771	0	16	9.29	3.13	-0.262	0.088	-0.352	0.176
A5 (max 16)	772	0	13	6.50	2.35	0.232	0.088	-0.169	0.176
ECODIES (max 78)	771*	16	59	**37.14**	6.74	-0.084	0.088	-0.171	0.176

Note:

- A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving
- **(*)** Refers to the number of students who provided responses to all knowledge-ability test items pertaining to the five areas that make up the entire test (ECODIES).

Average scores in each of the areas ranged between X_{A1}=5.32 and X_{A2}=9.66. Thus, students have greater knowledge and abilities in relation to *digital communication* (X_{A2}=9.66) and *safety* (X_{A4}=9.29), followed by *content creation* (X_{A3}=6.42) and *problem solving* (X_{A5}=6.50). The lowest score corresponded to the area of *information* (X_{A1}=5.32). The average score obtained in the final test was $X_{ECODIES}$=37.14 out of a maximum of 78 points.

A 10-point scale is the most widely used in the academic field for student assessment, compulsory education students scored close to satisfactory (4.8) on a 10-point scale.

Outcomes for some areas such as A1, A3 and A5 (table 4) were positively skewed (>0). This means that the curve shifted from the center to the right of the mean. With regards to kurtosis, values were lower than 3 and were negative in all cases, producing a platykurtic distribution. Values lower than 0 also revealed large data dispersion, demonstrated a lack of response unanimity. In each of the five areas, attitude items produced the following statistical data (table 5).

Table 5. Descriptive statistics for the ECODIES attitudes test

Areas	N	Min.	Max.	χ	$\bar{x}$	Skewness		Kurtosis	
						Y_1	SE	g2	SE
A1 (max 30)	806	0	30	24.80	4.06	-2.12	0.086	8.82	0.171
A2 (max 30)	788	0	30	26.02	4.32	-2.39	0.087	9.06	0.173
A3 (max 30)	777	0	30	25.21	4.05	-1.94	0.088	7.45	0.175
A4 (max 30)	767	0	30	26.04	4.14	-2.09	0.088	6.81	0.176
A5 (max 30)	760	0	30	25.08	4.39	-2.40	0.088	9.87	0.176
ECODIES (max 150)	760*	65	150	**127.2**	11.17	-1.23	0.089	3.20	0.179

Note:

- A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving
- **(*)** Number of students responding to all items on the attitudes scale in the five areas that make up the overall test (ECODIES).

Students' attitudes were seen to be highly positive in relation to the five areas that make up digital competence. Average scores ranged between X_{A1}=24.80 and X_{A4}=26.04, with a maximum of 30 being possible. Thus, students have better attitudes towards the fields of *safety* (X_{A4}=26.04) and c*ommunication* (X_{A2}=26.02), followed by *content creation* (X_{A3}=25.21) and *problem solving* (X_{A5}=25.08). The lowest score was obtained in relation to the area of *information* (X_{A1}=24.80).

As shown in table 5, data for all scale areas were negatively skewed (<0). Kurtosis was greater than 3 for all areas and positive in all cases, revealing a leptokurtic distribution. If the entire test is analyzed according to competence fields (knowledge, ability and attitudes), attitudes were generally seen to be more positive (X_{AC}=4.24) than they were towards the fields of knowledge and ability. The overall score was calculated using a 10-point scale as a reference. The overall score calculated for the fields of knowledge and ability in area 1 was 4.40, which is close to the midpoint. In contrast, the score for attitudes was high (8.26). In area 2, the overall score in the fields of knowledge and ability was 6.22, which is above the midpoint, whilst attitude scores were very high (8.68). In area 3, the overall score in knowledge and ability was 4.01, with this being below the midpoint, whilst the attitude score was very high (8.40). In area 4, the overall score for knowledge and ability was 5.80, with this being above the midpoint, whilst the score for attitudes was very high (8.80). In area 5, the overall score for knowledge and ability was 4.06, with this being below the midpoint, whilst the score for attitudes was very high (8.36). According to these data, compulsory education students have an average level of digital competence in areas 2 and 4 (*communication* and *safety*), and a low level in areas 1, 3 and 5 (*information*, *content creation* and *problem solving*).

In general, differences in scores obtained for the areas of knowledge and ability were very small, being barely noticeable. The standard deviation calculated for the overall test suggest it demonstrates variability and is capable of differentiating between subjects' competence levels (table 6).

Table 6. Descriptive analysis outcomes for the different areas of the fields of competence

Area	Field of competence	Min.	Max.	Mean	SD
A1	Knowledge (max. 6)	0	6	2.94	1.280
	Ability (max. 6)	0	6	2.38	1.286
	Attitudes (max. 30) **N=806**	0	30	24.80	4.064
	Test k-a area 1 (max. 12) N=816	**0**	**11**	**5.32**	**2.043**
A2	Knowledge (max. 8)	0	8	4.27	1.611
	Ability (max. 10)	0	10	5.39	1.926
	Attitudes (max. 30) **N=788**	0	30	26.02	4.320
	Test k-a area 2 (max. 18) N=807	**0**	**17**	**11.19**	**2.987**
A3	Knowledge (max. 6)	0	5	2.75	1.234
	Ability (max. 10)	0	9	3.67	1.707
	Attitudes (max. 30) **N=777**	0	30	25.21	4.049
	Test k-a area 3 (max. 16) N=787	**0**	**16**	**6.42**	**2.349**
A4	Knowledge (max. 6)	0	7	3.50	1.476
	Ability (max. 10)	0	10	5.79	2.129
	Attitudes (max. 30) **N=767**	0	30	26.04	4.139
	Test k-a area 4 (max. 16) N=771	**0**	**16**	**9.29**	**3.129**
A5	Knowledge (max. 6)	0	7	2.85	1.280
	Ability (max. 10)	0	9	3.65	1.670
	Attitudes (max. 30) **N=760**	0	30	25.08	4.399
	Test k-a area 5 (max. 16) N=772	**0**	**13**	**6.50**	**2.356**
Final test: knowledge-ability (5 areas). Max. 78 points (N=771)		16	59	**37.14**	6.74
Final test: attitude (5 areas). Max. 150 points (N=760)		65	150	**127.2**	11.17

Note:

- A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving.
- k-a test. Knowledge-ability test.

Difficulty/ease indices relating to knowledge and ability items

These indices are expressed as the likelihood of providing the correct response in relation to the fields of knowledge and ability in the different competence areas (tables 7 and 8). The overall data obtained reveal an average 47% success rate for the 78 items. This provides empirical evidence of the tool's moderate difficulty and is in line with that predicted by the experts. With regards to the items used to assess abilities, correct responses accounted for 48.4% of responses, whilst 45.7% of responses assessing knowledge were correct (with both suggesting moderate difficulty). There are virtually no differences between these competence fields unless attention is paid to the percentage of correct responses according to different areas. As already mentioned in the previous section, this percentage is higher, suggesting that competence is greater in relation to the areas of *safety* and *communication* (54.8% and 53.6%, respectively), and lower in relation to *content creation* (38.7%).

Thus, it can be stated that the tests were moderately difficult in the 5 areas (41%-60% correct responses) and that area 3 was found to be most difficult (15%-40%) (content creation).

Table 7. Difficulty/ease index of the knowledge-ability items, according to area

Area	Competency	N Item	N	N responses	% correct
A1	**Total items**	**12**	**816**	**362**	**44.5%**
	Knowledge items	6	816	400	49%
	Ability items	6	816	324	40%
A2	**Total items**	**18**	**807**	**433**	**53.6%**
	Knowledge items	8	807	431	53.4%
	Ability items	10	807	435	53.9%
A3	**Total items**	**16**	**787**	**348.7**	**38.7%**
	Knowledge items	5	787	400	39.7%
	Ability items	11	787	297.4	37.8%
A4	**Total items**	**16**	**771**	**423.2**	**54.8%**
	Knowledge items	6	771	400	51.8%
	Ability items	10	771	446.4	57.9%
A5	**Total items**	**16**	**772**	**339.1**	**43.4%**
	Knowledge items	5	772	371.4	48.1%
	Ability items	11	772	306.9	38.8%

Note: A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving

The percentage of correct responses shows that ECODIES is a balanced test (table 8) as similar difficulty was seen across the fields of knowledge and ability. In relation to all five areas, items were mostly attributed intermediate or moderate difficulty levels (40%-60%). This suggests better differentiation, with few items falling into either of the most extreme categories (very easy-very difficult).

Table 8. Difficulty/ease index in relation to the ECODIES test

	Blocks	N Item	N	% correct
ECODIES test (knowledge-ability)	**Total**	**78**	**771**	**47%**
	Knowledge items	30	771	48.4%
	Ability items	48	771	45.7%

Tables 9 and 10 present the structures of all of the competence area tests. All of the 78 items were divided between basic or easy (+60% success), intermediate or moderate (between 40% and 60% success) and advanced or difficult (below 40% success) difficulty levels.

Table 9. Item difficulty/ease index in relation to the final test

Description	Level	N items	% items
Easy	Basic	19	24.7
Moderate	Intermediate	36	45.5
Difficult	Advanced	23	29.9

Table 10. Structure of the ECODIES test according to item difficulty indices

	Items	N items	% success	Criterion	Description	Level
Area 1	5, 6	2	68.8; 79.5	61-85	Easy	Basic
	1, 4, 7, 8, 9, 10, 11, 12	8	44.2; 41.3; 46.9; 42.6; 33.5; 41.3; 47.5, 41	41-60	Moderate	Intermediate
	2, 3	2	26.7; 19	15-40	Difficult	Advanced
	Items	**N items**	**% success**	**Criterion**	**Description**	**Level**
Area 2	1, 6, 8, 15, 16, 17	6	81.2; 79.1, 66.8; 77.3; 62.1; 61.8	61-85	Easy	Basic
	2, 5, 9, 11, 12, 13, 14, 18	8	59.4; 44.6; 53.5; 47.8; 44.7; 57, 59.7; 45.2	41-60	Moderate	Intermediate
	3, 4, 7, 10	4	31.1; 22.7; 36.6; 35.1	15-40	Difficult	Advanced
	Items	**N items**	**% success**	**Criterion**	**Description**	**Level**
Area 3	3, 13	2	75.5; 66.8	61-85	Easy	Basic
	1, 2, 4, 8, 9, 14, 16	7	60.5; 56.8; 43.2; 41.6; 42.9; 48.4; 42	41-60	Moderate	Intermediate
	5, 6, 7, 10, 11, 12, 15	7	40.4; 37.6; 15; 40.7; 38; 20.7; 14.6	15-40	Difficult	Advanced
	Items	**N items**	**% success**	**Criterion**	**Description**	**Level**
Area 4	1, 4, 6, 9, 10, 11, 16	7	77.7; 61.3; 62.6; 63; 81.3; 70, 69.8	61-85	Easy	Basic
	2, 3, 7, 12, 13, 15	6	50.1; 54.7, 54.2; 56; 55.5; 41.6	41-60	Moderate	Intermediate
	5, 8, 14	3	39.8; 39.8; 12.5	15-40	Difficult	Advanced
	Items	**N items**	**% success**	**Criterion**	**Description**	**Level**
Area 5	6,7	2	71.5; 82	61-85	Easy	Basic
	1,2,3,9,10,11,12,15	8	43.6; 40.9; 55.7; 46.8; 46.8; 44.9;50.3; 48.7	41-60	Moderate	Intermediate
	4,5,8,13,14,16	6	21.7;34; 20.13; 32.8; 32; 23.1	15-40	Difficult	Advanced

Test reliability and validity

In order to examine reliability of both the overall entire test and according to the fields of knowledge, ability and attitude, Cronbach α and $\alpha_{ordinal}$, or common factor model, were calculated. These indices estimated internal consistency (Welch & Comer, 1998), together with Armor's Theta (principal-component model). The latter is considered more appropriate for scales that include fewer than five categories or for dichotomous items, with this being relevant here. In order to analyze the

Likert-type scale pertaining to attitudes, items were recoded. This scale is made up of 6 items with response options ranging from 1 to 5, however, the options of 4 and 5 were recoded to 1 (positive), whilst options 1, 2 and 3 were recoded to 0 (not positive). $\alpha_{ordinal}$ and Armor's Theta were calculated using tetrachoric correlations and rotated factor loadings. This was done following the instructions and Excel spreadsheet provided by Domínguez-Lara (2018).

Table 11 shows the data obtained according to each of the five competence areas. C*ronbach* α indices obtained for the different areas and fields were not acceptable (<0.70). This may be because this measure is designed for continuous variables and is considered to be inappropriate for scales with fewer than five categories. In consideration of observations made by other authors (Zumbo et al., 2007; Oliden & Zumbo, 2008) regarding the use of this index, the dichotomous nature of the scale led us to employ an attenuation rate in order to compare *Cronbach's* α and $\alpha_{Ordinal.}$ (table 15). Satisfactory values were obtained in almost every case (>0.70), with the exception of areas 1 and 3 in the field of knowledge and ability. Although indices were very close to 0.70, they fell below this minimum value for establishing acceptability and are, therefore, unable to guarantee scale reliability (Morales et al., 2003).

Test items with indices below 0.70 should be revised. Questions should be modified or changed in order to increase reliability in the specific context of the studied competence areas.

Table 11. Reliability of the overall test, according to fields and areas

Area	Field	N	Cronbach α	$\alpha_{ordinal}$	Armor's Theta	Attenuation Rate	N elements
A1	Knowledge-ability	816	0.393	0.655	0.66	40%	12
	Attitudes	806	0.593	0.724	0.72	18%	6
	Overall	**806**	**0.349**	**0.817**	**0.72**	**57%**	**18**
A2	Knowledge-ability	807	0.583	0.700	0.71	17%	18
	Attitudes	788	0.728	0.814	0.80	11%	6
	Overall	**788**	**0.397**	**0.864**	**0.80**	**19%**	**24**
A3	Knowledge-ability	787	0.434	0.628	0.64	31%	16
	Attitudes	777	0.694	0.798	0.72	13%	6
	Overall	**777**	**0.296**	**0.848**	**0.72**	**65%**	**22**
A4	Knowledge-ability	771	0.636	0.760	0.74	16%	16
	Attitudes	767	0.781	0.843	0.83	7%	6
	Overall	**767**	**0.393**	**0.895**	**0.84**	**56%**	**22**
A5	Knowledge-ability	772	0.398	0.582	0.62	32%	16
	Attitudes	760	0.681	0.790	0.70	14%	6
	Overall	**760**	**0.302**	**0.835**	**0.70**	**64%**	**22**
	Entire ECODIES test	760*	0.310	0.628	0.54	51%	108

Note:

- A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving.
- (*) Number of students who responded to all items of the knowledge-ability tests and the attitudes scale in the five areas that make up the entire test (ECODIES).

Both content and construct validity were considered. With regards to content validity, members of the research team formed an experts panel to analyze item pertinence and clarity in relation to theoretical assumptions (DigComp conceptual model) and their relationship with the defined dimensions. All items were created using the indicator model and were adapted to the age of the sample. They were submitted to expert review through discussion groups until a final version was drawn up following the reformulation of item

statements and response options. As for construct validity, principal component factor analysis (FA) was performed of the different categories (table 12). The fields of knowledge and ability were used as variables, alongside the attitudes scale. Analysis suitability was previously assessed using the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity for the overall instrument in relation to the knowledge and ability field (table 12). This analysis yielded a KMO value higher than 0.50 (a low but acceptable index) in all cases and so the sample can be considered to be adequate (Kaiser, 1974). Further, Bartlett's sphericity index was highly significant in all cases ($p<0.001$). This reflects positive data correlation and establishes a linear relationship between variables, suggesting that they were potentially factorizable. The sample for the attitudes scale was adequate. The KMO index obtained for this scale was higher than 0.50 and the Bartlett's sphericity index was also highly significant ($p<0.001$). Thus, these results suggest that factor analysis was appropriate.

Table 12. Sample suitability index for the knowledge-abilities and attitudes scales

Knowledge-ability areas	**Keiser-Meyer-Olkin measure**	**Bartlett's chi-square**	**df**	**Sig.**
A1	0.55	56.137	3	0.000
A2	0.77	802.688	45	0.000
A3	0.71	319.01	15	0.000
A4	0.60	104.89	6	0.000
A5	0.53	93.07	6	0.000
ECODIES Test (Knowledge-ability)	0.502	664.36	10	0.000

Attitudes	**Keiser-Meyer-Olkin measure**	**Bartlett's test**		
		Chi-square	Gl	Sig.
Overall attitudes scale	0.506	724.7	10	0.000

Note: A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving

This prior analysis allowed the application of factor analysis (FA) through the examination of principal components using Kaiser-normalized varimax rotation. The fields of knowledge and ability in relation to each competence area were used as variables, alongside the items pertaining to the attitudes scale. Each area was analyzed separately (table 13). Multivariate analysis techniques were used to reduce a group of interrelated variables in a set of independent factors to the smallest number possible. Correlations between variables were conducting to reduce data and simplify the structure (Casillas-Martín et al., 2018).

Table 13. Total variance explained by areas

Area	Competences	Extraction of sums of square loads		
		Total	**% of variance**	**Cumulative %**
A1	C1. Browsing, searching and filtering information	2.52	26.21	26.21
	C2. Evaluating information	1.26	13.07	39.28
	C3. Storing and retrieving information	1.19	12.40	**51.68**
	Attitude 1	1.04	10.84	62.52
	Attitude 2	0.91	9.40	71.92
	Attitude 3	0.81	8.37	80.29
	Attitude 4	0.71	7.41	87.70
	Attitude 5	0.69	7.12	94.81
	Attitude 6	0.50	5.19	**100.000**
A2	C1. Interacting through new technologies	3.01	25.11	25.11
	C2. Sharing information and content	1.46	12.18	37.29
	C3. Engaging in citizenship online	1.13	9.44	46.73
	C4. Collaborating through digital channels	0.95	7.88	54.61
	C5. Netiquette	0.89	7.44	62.05
	C6. Managing digital identity	0.79	6.61	**68.66**
	Attitude 1	0.75	6.27	74.93
	Attitude 2	0.70	5.83	80.76
	Attitude 3	0.69	5.74	86.50
	Attitude 4	0.61	5.10	91.60
	Attitude 5	0.53	4.45	96.05
	Attitude 6	0.47	3.95	**100.000**
A3	C1. Developing content	2.51	25.14	25.14
	C2. Integrating and elaborating	1.36	13.62	38.76
	C3. Copyright and licenses	0.99	9.88	48.64
	C4. Programming	0.86	8.60	**57.24**
	Attitude 1	0.84	8.38	65.62
	Attitude 2	0.81	8.13	73.74
	Attitude 3	0.71	7.09	80.83
	Attitude 4	0.67	6.73	87.56
	Attitude 5	0.66	6.60	94.16
	Attitude 6	0.58	5.84	**100.000**
A4	C1. Protecting devices	3.25	32.52	32.52
	C2. Protecting personal data	1.59	15.88	48.40
	C3. Protecting health	0.85	8.55	56.95
	C4. Protecting the environment	0.79	7.91	**64.86**
	Attitude 1	0.74	7.45	72.31
	Attitude 2	0.68	6.81	79.12
	Attitude 3	0.64	6.41	85.52
	Attitude 4	0.54	5.40	90.92
	Attitude 5	0.48	4.82	95.75
	Attitude 6	0.43	4.25	**100.000**
A5	C1. Solving technical problems	2.40	24.03	24.03
	C2. Identifying needs and technological responses	1.34	13.39	37.42
	C3. Innovating and creatively using technology	1.13	11.31	48.73
	C4. Identifying digital competence gaps	0.90	8.99	**57.72**
	Attitude 1	0.87	8.74	66.46
	Attitude 2	0.80	7.99	74.45
	Attitude 3	0.70	7.03	81.48
	Attitude 4	0.65	6.53	88.00
	Attitude 5	0.61	6.05	94.06
	Attitude 6	0.59	5.94	**100.000**

Note: A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving

The competence area with the strongest load in the knowledge and ability test was *information*, whilst *problem solving* had the weakest load. Highly similar results were obtained in the field of attitudes (table 14).

Table 14. Total variance explained in relation to each competence area in the fields of knowledge-ability and attitudes

Area	Extraction of sums of square loadings for knowledge-ability		
	Total	**% of variance**	**Cumulative %**
A1	1.77	35.45	35.45
A2	1.01	20.38	55.83
A3	1.002	20.03	75.87
A4	0.96	19.31	95.18
A5	0.24	4.81	100
Area	**Extraction of sums of square loadings for attitudes**		
	Total	**% of variance**	**Cumulative %**
A1	1.80	36.10	36.10
A2	1.09	21.82	57.92
A3	0.98	19.59	77.51
A4	0.91	18.18	95.70
A5	0.21	4.30	100

Note: A1. Information, A2. Communication, A3. Content creation, A4. Safety, A5. Problem solving

As a part of principal component analysis, λ values were calculated for each factor, retaining those whose value was $\lambda \geq 1$. The fields of knowledge and ability explained more than 50% of the overall variance in all five areas (51.68%-68.66%), with the range of variance explained being between 48.32% and 31.34% in the attitudes field.

Following exploratory factor analysis (EFA) with the number of factors being set at two (factor 1: attitudes field, factor 2: knowledge and ability field), a bidimensional structure was obtained. This explained 100% of total variance and so confirmed the test's validity.

Skewness of each of the items was also found to range between -1 and +1, which legitimized the analysis. λ values were obtained for each factor through principal component analysis, retaining those whose value was $\lambda \geq 1$. The component matrix (table 15) clearly illustrates saturation in relation to the attitude items in factor 1, and knowledge and ability items in factor 2.

Most of the items in the different subareas analyzed achieved appropriate loading, with values higher than or very close to 0.40. They were, therefore, retained within the same factor in which they were established, both by the researchers and by the expert committee that validated the test's content. Items corresponding to the area of attitudes produced significant loadings or high values in terms of factor interpretation, suggesting that they were crucial elements. It is worth noting that two low values emerged which pointed to weak loading in two subareas (<0.40) within the factor [area 3, *content creation*, subarea *copyright and licenses* (λ=0.232); area 5, *problem solving*, subarea *innovating and creatively using technology* (λ=0.184)].

Table 15. Principal component matrix

Areas	Variables	Factor	
		1	2
Area 1. Information	C1. Browsing, searching and filtering information	-0.080	**0.680**
	C2. Evaluating information	0.329	**0.515**
	C3. Storing and retrieving information	0.090	**0.682**
	Attitude 1	**0.390**	0.311
	Attitude 2	**0.398**	0.135
	Attitude 3	**0.548**	0.111
	Attitude 4	**0.743**	0.043
	Attitude 5	**0.714**	-0.018
	Attitude 6	**0.538**	0.049
Area 2. Communication	C1. Interacting through new technologies	0.006	**0.339**
	C2. Sharing information and content	0.091	**0.559**
	C3. Engaging in citizenship online	0.110	**0.602**
	C4. Collaborating through digital channels	0.026	**0.579**
	C5. Netiquette	0.207	**0.630**
	C6. Managing digital identity	0.74	**0.468**
	Attitude 1	**0.563**	0.198
	Attitude 2	**0.692**	0.148
	Attitude 3	**0.722**	0.121
	Attitude 4	**0.642**	-0.065
	Attitude 5	**0.584**	0.166
	Attitude 6	**0.698**	0.022
Area 3. Content creation	C1. Developing content	0.135	**0.662**
	C2. Integrating and elaborating	-0.031	**0.664**
	C3. Copyright and licenses	-0.032	**0.232**
	C4. Programming	0.122	**0.665**
	Attitude 1	**0.641**	0.038
	Attitude 2	**0.641**	0.075
	Attitude 3	**0.632**	0.218
	Attitude 4	**0.661**	0.015
	Attitude 5	**0.651**	0.019
	Attitude 6	**0.559**	-0.134
Area 4. Safety	C1. Protecting devices	-0.018	**0.691**
	C2. Protecting personal data	0.080	**0.718**
	C3. Protecting health	0.128	**0.707**
	C4. Protecting the environment	0.177	**0.549**
	Attitude 1	**0.528**	0.093
	Attitude 2	**0.717**	0.183
	Attitude 3	**0.676**	0.230
	Attitude 4	**0.757**	0.035
	Attitude 5	**0.701**	-0.030
	Attitude 6	**0.755**	0.100
Area 5. Problem solving	C1. Solving technical problems	0.027	**0.698**
	C2. Identifying needs and technological responses	0.029	**0.462**
	C3. Innovating and creatively using technology	0.014	**0.184**
	C4. Identifying digital competence gaps	0.037	**0.754**
	Attitude 1	**0.641**	0.117
	Attitude 2	**0.637**	0.137
	Attitude 3	**0.598**	0.243
	Attitude 4	**0.661**	-0.086
	Attitude 5	**0.665**	-0.033
	Attitude 6	**0.528**	-0.057

Note:

- Extraction method: principal components analysis.
- Rotation method: Varimax with Kaiser normalization.

Discussion and conclusions

The assessment of digital competence in the area of education remains a topic of great interest within the scientific community, with numerous studies already available (Casillas-Martín et al., 2020; He et al., 2020; Moreno Rodríguez et al., 2018; Nowak, 2019; Pérez-Rodríguez et al., 2019; Terry et al., 2019; Torres-Hernández et al., 2019; Xu et al., 2019, among others). Research along these lines can provide crucial information to guide educational policies aimed at the development of digital competence and the integration of ICT in education systems across countries.
In order for this information to be useful, research should have valid and reliable data gathering instruments available (Casillas-Martín et al., 2018). Such instruments must be able to reveal student deficiencies in the field and provide reliable information about their digital competences.

Statistical analyses of the ECODIES test confirmed that it is a reliable and valid instrument. It was administered to a broad sample and sufficient data was yielded to uncover the psycho-technical characteristics of the overall test.

It is evident that it is a very extensive tool which requires considerable time to be used in its entirety with the sample population. This is because it provides information in relation to the 21 competences included in the DigComp model.

Its difficulty/ease of use level in the fields of knowledge and ability was average/moderate, both for the overall test and for each of the areas. The field of attitudes obtained a very positive assessment (X_{AC}=4.24). This leads us to confirm that the attitudes of assessed students towards learning and adequate ICT use were very good.

The average score produced for the final test was $X_{ECODIES}$=37.14 out of a maximum of 78 points. This score is very close to satisfactory (4.8) on a 10-point scale. The test could be administered to students enrolled at higher educational levels in order to analyze differences between a variety of populations, in addition to examining progress in relation to this competence, within a defined group, throughout academic training.

Outcomes pertaining to $\alpha_{ordinal}$ show between satisfactory and very satisfactory reliability of all of the test areas (knowledge, ability and attitudes) and the overall test. However, tests corresponding to those areas where reliability indices were lower should be revised (A1 and A3 in the fields of knowledge and ability).

With regards to validity, the test was seen to be valid in that it covers all of the competences presented in the DigComp model. Factor analysis (FA) results show the existence of two clearly differentiated factors (1: knowledge and ability, 2: attitudes).

In summary, the ECODIES test has good psychometric properties and can, therefore, be defined as a reliable and valid instrument for the assessment of digital competence.

Scientific literature covers a wealth of tools aimed at assessing this competence in students. Most of these have certain limitations, including the following: (a) they are based on individual self-assessment and, although valid and reliable, results and conclusions may be biased since they are based on participant's subjective responses. It is, therefore, impossible to draw conclusions beyond what the assessed subjects wish to express; (b) they only assess some of the dimensions of digital competence; (c) there is a lack of psychometric studies on the instruments (González-Segura et al., 2018; Valverde Berrocoso et al., 2012).

The main contribution of the present study is the analysis of a test to assess the digital competence of compulsory education students (ECODIES). This is an original and novel tool that directly measures digital competence, according to numerous dimensions, through the use of reflection based on real situations and problem solving. This test is available to all of the scientific and educational community (https://gredos.usal.es/handle/10366/139397) who wish to use it to assess students' digital competence.

Open data, ethics and conflict of interest declarations

The data presented in the present research can be accessed by contacting the authors. The data are property of the University of Salamanca and will be disclosed with the institution's permission.

Participation in the study was voluntary and data were kept anonymous and confidential. There are no potential conflict of interests.

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