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ORIGINAL ARTICLE

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Development and validation of a test for measuring primary school students' effective use of ICT: The ECC-ICT test

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Abstract

Background: A practical test that measures the information and communication technology (ICT) skills students need for effectively using ICT in primary education has yet to be developed (Oh et al., 2021). This paper reports on the development, validation, and reliability of a test measuring primary school students' ICT skills required for effectively using ICT (the ECC-ICT test).

Objectives: Based on existing literature, three ICT use domains were identified for effectively using ICT: *Effective*, *collaborative*, and *creative use* of ICT. For these three domains, 24 corresponding teaching objectives were identified from a widely used digital literacy framework. Thirty-four test items cover these teaching objectives in an online test.

Methods: A mixed-method approach was used for the ECC-ICT test. Four pilot rounds $^{(n=25)}$ implemented qualitative interviews for cognitive validity and refining the test items, followed by a qualitative usability study$^{(n=6)}$. Confirmatory factor analysis and ANOVA provided quantitative insight into the large-scale test administration$^{(n=575)}$.

Results and Conclusions: Composite reliability of our conceptual 3-factor confirmatory model showed that the test reliably measured primary school effective use of ICT ($\omega = 0.82$), collaborative use of ICT ($\omega = 0.80$) and creative use of ICT ($\omega = 0.64$). Convergent validity (ranging from 0.41 to 0.46) was acceptable. Internal consistency (ranging from 0.84 to 0.91) and discriminant validity (HTMT values below 0.90) are good. ANOVA results show that mean test scores are higher for students in higher grade levels ($p < 0.001$). The post hoc Bonferroni results show that most grade-by-grade comparisons are significant ($p < 0.001$).

KEYWORDS
assessment measurement, effectively using ICT, ICT skills, primary education

1 | INTRODUCTION

Students need information and communication technology (ICT) skills to use ICT tools in education confidently, satisfactorily, and persistently (Landrum, 2020). Young children must acquire at least rudimentary ICT skills to deal with digital devices, which can be expanded later in their education (Weber & Greiff, 2023). However, a review by Siddiq et al. (2016) found only a few ICT literacy assessments with performance-based tasks in primary education, and their focus on digital communication, collaboration, and creative problem-solving is limited. Most of the 38 tests reviewed by Siddiq target lower secondary education.

ICT tools are often used to support students in regulating their learning processes (Azevedo et al., 2019). Well-designed use of ICT in education can allow for features essential for personalising how students learn, monitoring individual progress, suggesting learning paths, and allowing students to move at their own pace (Sturgis & Patrick, 2010). This includes, for example, students using ICT to access digital educational resources, collaborating through video-conferencing software, and selecting digital tools to solve problems (Williams, 2013). ICT-skilled students can expand their education beyond classrooms and reach all corners of society (Amutha, 2020).

The skills to use ICT effectively are a cornerstone of the future curriculum (Supena et al., 2021). Using ICT effectively concerns 'teacher displays' and 'student displays', enabling students to gain information about their study behaviour and activities (Marquenie et al., 2014), but also interacting with computer-assisted learning systems such as intelligent tutoring systems, game-based learning environments, and virtual reality (Azevedo et al., 2019). Effectively using ICT is not an individual affair. It occurs in interaction with fellow students, teachers, parents, and the learning environment and requires participation in collaborative activities (Moje, 2015).

The rapid and continuous growth of the use of ICT and digital technology in education, and in particular effectively using ICT, requires students to have the necessary skills and competencies to perform tasks and solve problems using ICT (Fu, 2013; Martin & Grudziecki, 2006; Sarkar, 2012).

ICT skills are a subset of digital literacy skills (Reddy et al., 2020). According to Fu (2013), digital literacy is a set of skills students require to use digital tools, educational applications, and digitally sourced information to support achieving goals in school and life situations. If students are digitally literate, they can be confidently presented with ICT to support their learning. However, there is a large amount of research showing that students overestimate their ICT skills (Aesaert et al., 2017; Prior et al., 2016; Rohatgi et al., 2016; Rubach & Lazarides, 2021; Siddiq et al., 2016).

In summary, an objective, authentic assessment of primary students' ICT skills is needed. In the following paragraph, we will explain how we propose to measure ICT skills in the context of this study (Dutch students aged 7–12 years old). We will explore the existing appropriate frameworks and assessments and present our research question.

1.1 | Measuring ICT skills

The growing emphasis on ICT in education has sparked significant interest and involvement from various stakeholders, including researchers, policymakers, and national and international enterprises. Together, they have contributed to developing ICT literacy frameworks to outline and scrutinise the essential skills and competencies for thriving in work life and society (Binkley et al., 2012). ICT literacy plays a pivotal role in preparing individuals for the challenges of the modern world (Voogt et al., 2013).

As the importance of ICT literacy continues to prominence, there is a pressing need to evaluate students' proficiency in mastering these critical competencies. Such knowledge is essential from multiple perspectives, including informing educational policy, enhancing teachers' instructional practices, and designing programs to prepare the next generation for the dynamic working life of tomorrow. To accomplish this task effectively, reliable, authentic, and valid measurement instruments are imperative, enabling the comprehensive monitoring of student's progress in mastering these complex and multi-faceted competencies. The assessment of ICT skills needs to reflect authentic, real-life situations as closely as possible (Fraillon, 2018). Recent studies by Lazonder et al. (2020) and Ihme et al. (2017) challenge the assumption that these skills are task and tool-independent.

We propose that an authentic, contextual ICT assessment for young students in Dutch elementary schools (7–12 years old) contains three domains of ICT skills. These three domains are the *effective*, *collaborative*, *and creative* use of ICT. The three domains are common across frameworks such as the seven core skills (*Technical*, information, communication, *collaboration*, critical thinking; *creativity*, and problem-solving skills) by Van Laar et al. (2020), the 4C (*Constructive*, Critical, *Creativity*, *Collaborative*) learning model by Supena et al. (2021), and the NETS-S (*Creativity*, *Collaboration*, Research, Critical thinking, Citizenship, *Technological Operations*) by the International Society for Technology in Education (2007).

We excluded domains that were not expected to progress (the Dutch primary education curriculum does not teach ICT skills explicitly (van Rooyen et al., 2021)) or were too difficult for young students in elementary school (7–12 years old) (Weber & Greiff, 2023). To our knowledge, this paper presents the first assessment covering *effective*, *collaborative*, *and creative* use of ICT. We named this the ECC-ICT test. Our study was designed to answer the following question:

> Is the ECC-ICT test valid and reliable for primary school students' effective, collaborative, and creative use of ICT tools?

Other assessments covering the *effective*, *collaborative*, *and creative use of ICT tools* begin measurement later than the proposed ECC-ICT assessment in this study (7–12 years old) and have not been developed and validated for the proposed Dutch context in this study. For example, Only one of the assessments summarised in the UNESCO 2023 report on Digital Literacy Assessment (Reichert et al., 2023) explicitly covers our proposed domains; the ST2L tested in the US with participants aged 13 (Hohlfeld et al., 2010). This assessment is based on the U.S National Educational Technology Standards for Students.

We addressed the absence of a test of the skills young Dutch students (7–12 years old) need to use ICT effectively, collaboratively, and creatively by developing and validating this test for the Dutch context in this study.

2 | DEVELOPMENT OF THE ECC-ICT TEST

This section describes the four-step procedure we used to develop an ECC-ICT test. First, we defined the effective, collaborative, and creative use of ICT. In the second step, we selected a digital literacy framework specific to the Dutch context with many teaching objectives (e.g., *"Today, you will learn how to use a simple communication application"*) for primary school students. This helped us to transfer the more generally formulated conditions into concrete teaching objectives in the third step. In this third step, we used the digital literacy framework to translate the selected conditions (domains) into 24 learning objectives (e.g., *"the student can make effective and efficient use of communication applications for collaboration"*). In the fourth and final step, we used the list of 24 learning objectives to design test items for our ECC-ICT test. These four steps are described in further detail below.

2.1 | Step 1: Defining the effective, collaborative, and creative use of ICT

The effective use of ICT tools relates to the skill of using ICT resources (such as devices, applications, or infrastructures) to fulfill immediate learning needs and communicate with a broader audience (Williams, 2013). To meet immediate learning needs, a student needs the skill to access educational resources, such as video tutorials, online resources, and blended learning activities, not limited to the classroom (Martin, 2008). To communicate with a broader audience than the classroom, a student needs to be able to access various mass media (such as social media, wiki, and blog pages) (Fraillon et al., 2019).

The collaborative use of ICT tools relates to students seeing themselves as participants and contributors in real-time and non-real-time collaboration beyond the classroom (Hobbs, 2017; Williams, 2013). Real-time collaboration regards collaboration beyond the classroom's physical limits (e.g., using video conferencing software). An example of non-real-time collaboration is using mail and word-processing software to receive feedback from the teacher or peers (Huggins et al., 2014). This collaboration beyond the classroom can create engagement and relevance for the learning task by engaging communities of like-minded peers or experts (Gourlay et al., 2021).

The creative use of ICT. Two criteria define creativity: novelty and usefulness (Plucker et al., 2004; Simonton, 2000; Sternberg & Lubart, 1998). We focus on usefulness because primary students are still in the basic stages of ICT skill development (the Dutch primary education curriculum does not teach ICT skills explicitly (van Rooyen et al., 2021)). Therefore, we do not expect novel (unique or original) behaviour (Plucker et al., 2004; Potters et al., 2023). Examples of usefulness are selecting digital tools and technologies that can be used to compose digital products (Hobbs, 2017), create knowledge (International Society for Technology in Education, 2007), and select a suitable digital device application or platform (Järvelä, 2006; Munakata & Vaidya, 2013).

Our next step was to select a digital literacy framework to define the effective, collaborative, and creative use of ICT for primary education more concretely in the form of concrete learning objectives.

2.2 | Step 2: A digital literacy framework to interpret ICT's effective, collaborative, and creative use of ICT

A general framework used to interpret digital literacy for primary education students in the Dutch language is provided by the Dutch Foundation for Curriculum Development (SLO) (SLO, 2021; Thijs et al., 2014). The SLO framework describes teaching objectives and learning objectives. The SLO's theoretical base follows the three literacy domains by Lau and Yuen (2014). Lau and Yuen (2014) define Digital literacy as literacy on information, media, and ICT (Lau & Yuen, 2014). Regarding information literacy, the SLO's teaching objectives are sourced from the American Library Association (Iannuzzi, 2000) and Kurbanoğlu et al.'s (2006) information literacy scales. Brand-Gruwel & Wopereis (2019) translated and validated these information literacy objectives into Dutch information literacy scales. Regarding media literacy, the SLO's teaching objectives were sourced from Koc and Barut's (2016) new media literacy scale. These media literacy objectives were translated and validated into Dutch media literacy scales by Gillebaard et al. (2013). Regarding ICT literacy, the SLO's teaching objectives were sourced from Lau and Yuen's (2014) ICT literacy scale. Van der Kaap and Schmidt (2007) translated and validated these ICT-based skills for Dutch ICT literacy scales.

2.3 | Step 3: Selecting learning objectives for effective, collaborative, and creative use of ICT

We selected SLO teaching objectives that matched the conceptual descriptions of effective, collaborative, and creative use of ICT. The SLO's teaching objectives are sorted into four domains of skills: basic ICT skills, media literacy skills, information literacy skills, and computational thinking skills. They range in difficulty to cover the entirety of primary education. We added the words "*the student can*" to the selected teaching objectives to phrase them as measurable learning objectives (e.g., "*identify which machine has a computer of sorts*" becomes "*the student can identify which machine has a computer of sorts*. In all these examples below, we added the words "*the student can*" to form learning objectives.

Using e-mail and word-processing software is part of the concept of collaborative use of ICT. For this reason, we selected the learning objectives "*The student can use word processing applications for writing text*" and "*The student can communicate through email or similar applications*".

Accessing educational resources such as video tutorials, online resources, and blended learning activities is part of the concept of effective use of ICT. For this reason, we selected the learning objectives "*The student can use the basic functionalities of an internet browser*", "*The student can use an internet browser to view websites and work with online educational applications*", and "*The student can pause, rewind, or review the instructional video*".

Selecting digital tools and technologies to solve problems is part of the concept of creative use of ICT. For this reason, we selected the learning objectives *"The student knows possibilities to solve a problem using a computer"*, *"The student can select digital appliances and technologies for a specific purpose"*, and *"The student can select digital applications for a purpose"*.

The final learning objectives for the ECC-ICT test are listed in Table 1. This list was used to develop the concrete items in the ECC-ICT test.

TABLE 1 Learning objectives related to the three domains of information and communication technology (ICT) use for effectively using ICT (translated from Dutch to English).

No.	Learning objective: The student ...
Effective use of ICT	
1.	Can pause, rewind, or replay an instructional video
2.	Can use the basic functionalities of an internet browser
3.	Can explore the internet in a secure environment
4.	Can use an internet browser to view websites and work with online educational applications
5.	Is familiar with different file formats and knows how to save, copy, delete, send, receive, or share these files
6.	Can use websites in search of information
7.	Can navigate to online sources of information
8.	Can identify the sources of information that can answer an information query
9.	Can assess if and where the requested information is available;
10.	Can formulate an effective and efficient search strategy
11.	Can adjust a search strategy if necessary
12.	Can gather and select information necessary to answer a query
13.	Can switch different information sources to compare information
14.	Can evaluate the usefulness, trustworthiness, and representativity of the found information
Collaborative use of ICT	
15.	Can use a communication application to share messages with others
16.	Can share his content on common communication media
17.	Can use word processing applications for writing text
18.	Can communicate with others through email or other communication applications
19.	Can choose an appropriate application to collaborate in the learning process
Creative use of ICT	
20.	Knows possibilities to solve problems using a computer.
21.	Recognises the functionalities of devices and can make choices in using media and devices
22.	Can select a suitable digital device or platform for a specific purpose
23.	Can select a suitable application for a specific purpose
24.	Can select a suitable application for creating content

2.4 | Step 4: ECC-ICT test development

The comprehensive test measures students' skills in the three domains of ICT use needed for effectively using ICT. We used the list of 24 learning objectives (see Table 1) to design test items for our ECC-ICT test. An extensive table detailing the link between learning objectives and questions is available under this OSF link (https://osf.io/6k5pr). In summary, the effective use of ICT was covered by Items 1, 2, 4, 5, 8, 9, 10, 11, 12, 13, 15, 17, 18, 19, 22, 25, 27, 28, 30 and 31. Collaborative use of ICT was covered by Items 4, 6, 14, 16, 19, 20, 23, 24, 26, 32 and 34. Creative use of ICT was covered by items 3, 5, 7, 15, 21, 29 and 33. The following items covered only one learning objective: 34, 32, 28, 26, 21, 16, 14, 13, 10, 9, 7, and 6. The following items covered two domains: 4, 5 and 19.

The ECC-ICT test was designed as an online test with item formats that can be answered by clicking or selecting answers. We created items that mimic ICT tasks to assess students' ICT skills (Reichert et al., 2020). ICT skills must be tested by employing simple, non-complex tasks and measures fit for children (Weber & Greiff, 2023). Different item types (hotspots, multiple choice, multiple response) were used to balance technological and information-related aspects of ICT skills (Ihme et al., 2017). Practical assignments were mocked with a screenshot of a simulated website or a software program. In these cases, hotspots were used to log the students' answers as coordinate data (*x*,*y*) or by selecting the correct multiple choice (MC) answer (see Figure 1). MC items were also used if the student needed to select a single textual answer (see Figure 2) or choose from several spots indicated by arrows (see Figure 3). Multiple response (MR) items were used if the student needed to select a combination of correct tools or applications to complete a task (see Figure 4). Note that the questions in Figures 1–4 were translated from Dutch to English. To determine which answering option is used for specific items, click this OSF link (https://osf.io/2ms7a). Figures 1 and 2 represent an example of a question for the Effective use of ICT. Figure 3 depicts an example of a question for the Collaborative use of ICT. Figure 4 illustrates an example of a question for the Creative use of ICT.

3 | RESEARCH QUESTION

Our research question was:

> Is the ECC-ICT test valid and reliable for primary school students' effective, creative, and collaborative use of ICT tools?

4 | METHOD

A mixed-method approach was used for the ECC-ICT test. Four pilot rounds $^{(n=25)}$ implemented qualitative interviews for cognitive validity, followed by a qualitative usability study ($n = 6$). The pilot test results also refined the test items to improve the test's validity. A quantitative

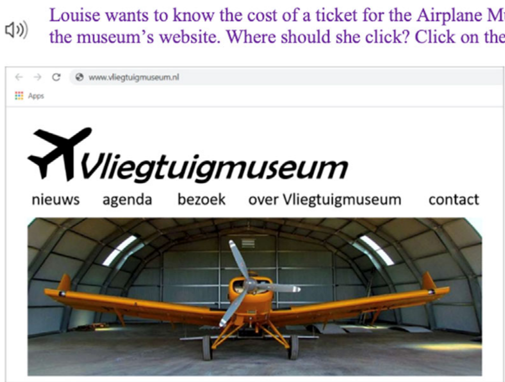

FIGURE 1 Example of hotspot item in the domain Effective use of information and communication technology (ICT). This item covers learning objectives 3, 6, 7, and 9 from Table 1.

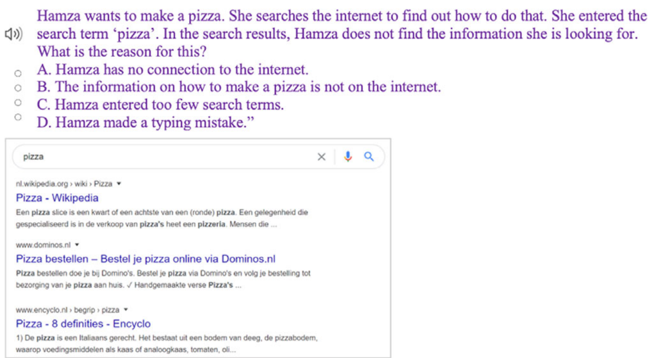

FIGURE 2 Multiple choice (MC) item with text answers in the domain effective use of information and communication technology (ICT). This item covers learning objectives 10 and 11 from Table 1.

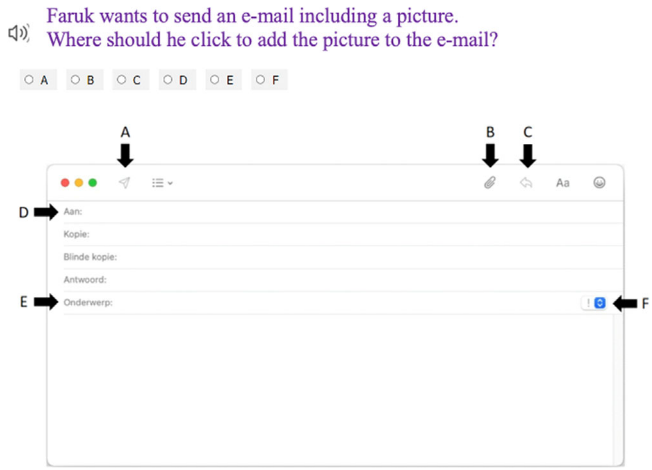

FIGURE 3 Example of an multiple choice (MC) item with a choice of clicking spots in the domain Collaborative use of information and communication technology (ICT). This item covers learning objectives 5, 16, and 18 from Table 1.

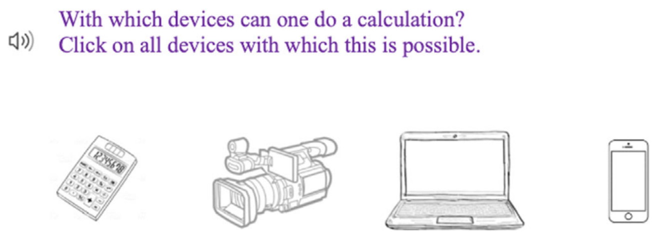

FIGURE 4 Example of an multiple response (MR) item (more than one answer can be chosen) in the Creative use of information and communication technology (ICT). This item covers learning objectives 3, 6, 7 and 9 from Table 1.

analysis of the large-scale test administration $^{(n=575)}$ using confirmatory factor analysis reported composite reliability, convergent validity, internal consistency, and discriminant validity. Finally, an ANOVA provides insight into the mean proportion of correct scores and the percentage of correctly answered questions (also called the *p* value).

The final ECC-ICT test was administered to a large sample of Dutch primary school students from Grades 2 to 6 (Dutch: 'group 4' to 'group 8'). Furthermore, we explored the test scores at different grade levels to examine whether the test scores improved at higher grade levels as an indication of test validity.

4.1 | Pilot study for cognitive validity

The ECC-ICT test was tested for cognitive validity using three pilot rounds, exploring if the test items triggered the expected cognitive process and if test items differentiated between novice and experienced students. The results of each pilot round were used to adjust or replace test items and, if necessary, add extra test items. A fourth pilot round assessed the usability of the digital environment we used to host the ECC-ICT test. This was done using observations and short interviews. Think-aloud protocols were used to obtain this information (Krahmer, 2004).

4.1.1 | Participants and procedure

The population needed for the pilot depends on the quality of the output when using the Think-aloud protocol (Virzi, 1992). Faulkner (2003) and Lewis (1994) advise interviewing at least five to 10 students. In the current study, we interviewed 25 students over four pilot rounds. The test items were presented to the students on a screen or paper in the first three pilot rounds. This was done with individual students or with small groups of students. We used level-three think-aloud interviews: The students were asked to answer the ECC-ICT test questions aloud so the researchers could determine if the correct cognitive response was triggered and which response was the logical result of the question's formulation.

The first pilot round included eight participants aged 7–12 (one student from Grade 2, three from Grade 4, and four from Grade 5).

Results from this round were used to revise how questions and answers were formulated in the ECC-ICT test and to replace five too-difficult items.

The second version of the ECC-ICT test was piloted with five students aged 7–11 (two students from Grade 2, one from Grade 3, one from Grade 4 and one from Grade 5). Results from the second round confirmed that the level of difficulty was improved. Because multiple test items did not cover several learning objectives, we developed seven new test items for the third round.

These seven new items were piloted in the third round, with six students aged 7–12 (one from Grade 2, one from Grade 3, one from Grade 4, one from Grade 5 and two from Grade 6). Results from this third round led to eight final adaptations of the wording of items (for example, an image of a turtle was referred to as a 'file'; this was changed to the word 'image') and answer options (for example: in selected MR questions, two answers instead of one were now required to increase difficulty).

The fourth pilot round focused on the usability of the online environment in which the test was administered. Six students aged 7–12 participated (two from Grade 3, two from Grade 4, one from Grade 5 and one from Grade 6). Each student was asked to complete the digital ECC-ICT test on a school computer. At the same time, they were observed online through screen sharing in a video-conferencing application (due to Corona regulations). After completing the test, the students were asked about their experiences handling the online environment. The results from the final pilot round were used to fine-tune answering options (e.g., one answering option in a question about video scrolling was interpreted by participants as pointing toward the end of a video timeline, while the 'full screen' button was the intended answering option). In addition, the order in which the test items were presented to the student was adjusted. One usability problem was detected where answering options were not visible without scrolling down. This problem was resolved by giving the answering options directly after the question. The final Effective ICT consists of 34 items. A video walk-through of the final test is at this OSF link (https://osf.io/z39ne). A PDF printout of the final test (in Dutch) can be found at this OSF link (https://osf.io/8sx57).

4.2 | Large-scale test administration

The ECC-ICT test was administered to students from eight Dutch primary schools. These schools were all working on educational developments to use ICT more effectively. We used the result of this large-scale administration to assess the reliability of the ECC-ICT test and explore the extent to which test scores differ by grade level.

4.2.1 | Participants and procedure

Students from Grades 2 to 6 (Dutch 'groep 4' to 'groep 8', ages 7–12) from these eight Dutch schools for primary education were asked to complete the ECC-ICT test. The eight schools' Social Economic Status (SES-WOA) range covers 0 (from −0,144 to 0,251). This indicates they are of comparable SES to the average Duch school. SES is accounted for because of the correlation between SES and ICT literacy (Falck et al., 2021; Scherer & Siddiq, 2019). Parents were asked to give their consent to participate in the research. A total of 609 students started the ECC-ICT test, of which 575 completed all test items (116 from Grade 2, 78 from Grade 3, 132 from Grade 4, 140 from Grade 5, and 126 from Grade 6). The teachers had the students complete the Effective ICT independently (without assistance from the teacher or peers), using a laptop, Chromebook, or PC and a Google Chrome-based browser. We advised the teachers to set the screen full to ensure the ECC-ICT test items were fully visible. The students were presented with an instruction video as preparation before starting the test. The introduction video for students is available at this OSF link (https://osf.io/x7vmd). The test began with five warm-up test items about topics unrelated to ICT so that the student could get used to the different item types (MC and MR items with textual or picture-based answer options and hotspot items). Each test item included a loudspeaker button that could be clicked to play an audio file reading aloud the text in the question and the answer options. This button was included to facilitate students who have difficulty reading.

5 | DATA ANALYSIS

The data from the 575 complete cases in the large-scale test administration were scored as incorrect (0) or correct (1) per item. For scoring the hotspot items (where students had to click on a screenshot), we defined the correct clicking areas of the screenshots using *x*- and *y*-coordinates. The answer was scored as valid if the coordinates of the point where the student clicked were within the defined set of (*x*, *y*) coordinates. The hotspot questions' specific (*x*, *y*) coordinates are available at this OSF link (https://osf.io/v876y).

We first examined the item statistics to check the quality of the individual items. Then, we performed a confirmatory factor analysis (CFA) to confirm our conceptual model of three domains of effectively using ICT. We tested the reliability of each of the domains. In addition, we examined the test's internal consistency. Finally, we explored the extent to which test scores differ by grade level.

5.1 | Item statistics and internal consistency

We looked at the correct proportion (difficulty level) and the item-total correlation for each item. We also examined item-total correlations for the distractors in the case of MC items. For test item 11, we detected a positive item-total correlation for one of the distractors ($r = 0.035$),[1] meaning that students with a higher total score tended to select this (incorrect) distractor. This distractor was, moreover, chosen by a higher percentage of students than the correct answer (45%

[1]Item 11.

vs. 32%). This indicates that this distractor was problematic, and the item's validity could be better. Therefore, we decided to exclude this item from all further analyses. Distractor analysis results of all MC items can be found at this OSF link (https://osf.io/eczs7).

5.2 | Confirmatory factor analysis

We used a confirmatory factor analysis (CFA) to test whether our conceptual model of three domains of use of ICT—*effective*, *collaborative*, and *creative use of ICT*—fits the data. The CFA was performed using the R package 'lavaan' v.0.6-8 (Rosseel et al., 2021). We ran the CFA using the diagonally weighted least squared estimator because the item scores are categorical: 0 (incorrect) or 1 (correct). Correlations between test items were tested beforehand, and two test items that correlated higher than 0.5 were defined as being correlated in the factor model.

We ran one, two, three, and five-factor models in the preparatory data analysis. We report the three-factor model because this model provided the best statistical fit and aligned with our conceptual model. However, most notably for teachers, a three-factor model is more informative on which factor a student needs support than a one or two-factor model. The comparison between models was calculated using Lavaan's lavInspect function using an ANOVA in Table 2 (Rosseel et al., 2021).

The fit of the three-factor model was assessed using the following fit indices: Root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker–Lewis index (TLI), standardised root mean square residual (SRMR), and chi-square. For RMSEA, values smaller than 0.06 indicate a good fit. CFI and TLI values above 0.95 denote a good fit (Xia & Yang, 2019). Furthermore, an SRMR value lower than 0.08 is considered a good fit (Henseler et al., 2014) and a Chi-Square value lower than 2 indicates a good fit (Alavi et al., 2020). The significance value 0.05 is represented by '*'.

5.3 | Reliability analysis

Reliability is the proportion of a factor model score's variance explained by a target construct (Savalei, 2019). Therefore, it is crucial to determine to what extent our ECC-ICT test represented that construct concerning its internal factor structure. Suppose reliability is estimated using the parameters of an incorrect (i.e., misspecified) factor model. In that case, the reliability estimate will likely be biased concerning measuring the target construct (Flora, 2020). Composite reliability is the reliability of observed scores calculated as composites (i.e., the sum or mean in a factor model) of individual test components (Lai, 2021). We focused on composite reliability using statistical methods that account for measurement error to produce an ECC-ICT test with replicable results (Savalei, 2019). The CFA output from Lavaan was used to calculate reliability using the R package 'semtools' v.0.5-4 (Jorgensen et al., 2021). The semtools package provides us with Cronbach's alpha and McDonald's omega. The

TABLE 2 Preparatory model comparison.

	df	χ^2	χ^2 diff	Diff	Pr (>χ^2)
Three factor	484	420.61			
Two factor	488	420.80	−0.5860	4	10.000
One factor	491	423.03	26.060	3	0.4564
Five factor	493	423.88	53.856	1	0.0203*

advantage of McDonald's omega (ω) compared to Cronbach's alpha is considering the strength of association between items in the factor modeling, resulting in a better internal consistency estimation (Dunn et al., 2014; McNeish, 2018). McDonald's omega can be viewed as the reliability controlling for the other factors and assumes that a model is a congeneric factor model where measurement errors are not correlated. We report McDonald's omega 3, as this is the most conservative method in calculating the coefficient of McDonald's omega (McNeish, 2018).

Keeping this test's practical application (in classrooms) in mind, reliability above 60% was considered highly reliable in educational science (Hair, 2014; Pett et al., 2003). 60% was deemed highly reliable because many factors impact a student's performance in practical classroom conditions. The value of 60% explained variance is used as a cut-off value to determine if our ECC-ICT test was reliable.

5.4 | Exploring test scores by grade level

To compare test scores between grade levels, we first calculated the proportion of correct scores per student for each domain of ICT use. Then, we performed a weighted one-way ANOVA for each domain to correctly compare these proportions across the different grade levels (Grade 2 to Grade 6). Weights were calculated so that students from bigger classes had proportionately lower weights. The weighting served to control for different numbers of participating students per grade level per school to cancel out any potential school effects.

6 | RESULTS

6.1 | Factor model fit

To answer our research question, we needed to check if the factor model sufficiently fitted our data so we could reliably interpret the model's results. Table 3 shows that the factor model resulted in a good fit according to the fit criteria by Xia and Yang (2019), Alavi et al. (2020), and Henseler et al. (2014). Thus, our three-factor model sufficiently fits the data. This means we can consider the test to consist of three subtests, one for each domain: *effective*, *collaborative*, and *creative use of ICT*. Factor loadings, distractor analysis, and item statistics can be found at this OSF link (https://osf.io/eczs7). A model-implied correlation matrix for the 34 items is available at this OSF link (https://osf.io/y95q6).

6.2 | Reliability and validity

Composite reliability results for the three subtests are presented in Table 4. The three subtests were highly reliable, with a reliability above 60% (Hair, 2014; Pett et al., 2003), with McDonald's omega3 values ranging from 0.65 to 0.82, meaning 65%–82% of the variance in the factor accounted for (Table 4).

Convergent validity is measured using the average variance extracted (AVE) about the amount of variance due to measurement error varied from 0.41 to 0.46 (Table 4). These are acceptable values in light of the high coefficient alpha values (Lam, 2012).

Internal consistency is measured using Cronbach alpha. These indices range from 0.84 to 0.91 (Table 4) and are well above the 0.7 threshold, indicating a good internal consistency (Hair et al., 2017).

Discriminant validity is measured using the heterotrait-monotrait ratio of correlations (HTMT). Henseler et al. (2015) indicate HTMT values below 0.90 indicate good discriminate validity. Table 5 shows that the HTMT values between the factors are below the 0.90 threshold, meaning we have good discriminant validity.

TABLE 3 Model fit of the conceptual 3-factor model.

CFI	TLI	RMSEA	SRMR	χ^2
1.00	1.00	0.02	0.07	0.99

TABLE 4 Composite reliability, convergent validity, and internal consistency results of the three subtests (domains).

Subtest (domain)	α	Omega3	Avevar
Effective use of ICT	0.91	0.82	0.41
Collaborative use of ICT	0.90	0.80	0.49
Creative use of ICT	0.84	0.65	0.47

6.3 | Test scores by grade level

Table 6 displays the mean proportion of correct scores for each domain of ICT use by grade level and the ANOVA results. The ANOVA results show that for all three domains, the mean test scores are higher for students in higher grade levels ($p < 0.001$). The post hoc Bonferroni results show that almost all grade-by-grade comparisons are significant ($p < 0.001$), with students from the higher grade level scoring higher than students from the lower grade level. Only between Grade 5 and Grade 6, no differences were found.

6.4 | Competence by grade level

To show the degree to which the students of that grade master the skill measured by this questionnaire, we looked at the percentage of correctly answered questions (also called the p-value). This percentage was adjusted for multiple-choice questions. We classify three categories of control; insufficient, moderate, and good (Scheltens et al., 2013). Less than half of the students answered the question correctly, which equals insufficient control. Between 50% and 80% of the students in the grade in question responded to the question correctly equals moderate control. More than 80% of the students answered correctly, equalling good control. Table 7 shows the results of the ICT test per domain. The first column shows the learning objectives. The remaining columns indicate to what extent the question was answered correctly per grade by colours.

TABLE 5 Discriminant validity of the conceptual 3-factor model.

	Effective use of ICT	Collaborative use of ICT	Creative use of ICT
Effective use of ICT	1.000		
Collaborative use of ICT	0.885	1.000	
Creative use of ICT	0.890	0.832	1.000

TABLE 6 Weighted mean proportion correct scores per domain by grade level and one-way ANOVA results comparing grade levels.

	Weighted mean proportion correct					ANOVA results	
Domain	G2	G3	G4	G5	G6	*F* (4, 579)	Post hoc Bonferroni tests
Effective use of ICT	0.46	0.61	0.75	0.84	0.87	167.2***	Significant differences between all grade levels ($p < 0.001$), except between G5 and G6
Collaborative use of ICT	0.32	0.55	0.70	0.82	0.87	214,4***	Significant differences between all grade levels ($p < 0.001$), except between G5 and G6
Creative use of ICT	0.67	0.82	0.90	0.95	0.95	75,7***	Significant differences between all grade levels ($p < 0.001$), except between G4, G5, and G6

Abbreviation: G, grade.
Note: Weighted averages of correct proportion were used to control for potential differences between schools.
***$p < 0.001$.

TABLE 7 The competence in effective, collaborative, and creative use of information and communication technology (ICT) by grade level.

Grade	2	3	4	5	6
Effective use of ICT					
Compare products online					
Understands computer folder structures					Light gray
Search in a webstore				Light gray	Light gray
Save file on a USB stick			Light gray	Light gray	Light gray
Navigate on a navigation website			Light gray	Light gray	Dark gray
Recognise relevant search result			Light gray	Light gray	Dark gray
Navigate to the asked information on a website			Light gray	Dark gray	Dark gray
Recognise reliable searchresult		Light gray	Light gray	Dark gray	Dark gray
Fast forward through video		Light gray	Light gray	Dark gray	Dark gray
Shoose the best search word		Light gray	Dark gray	Dark gray	Dark gray
Adjust search stratagy		Light gray	Dark gray	Dark gray	Dark gray
Search with search words	Light gray	Light gray	Dark gray	Dark gray	Dark gray
Recognise an audio file by its extension	Light gray	Light gray	Dark gray	Dark gray	Dark gray
Navigate to a previous site in a web browser	Light gray	Light gray	Dark gray	Dark gray	Dark gray
Finds adressbar in browser	Dark gray	Dark gray	Dark gray	Dark gray	Dark gray
Identifies information the internet can provide	Dark gray	Dark gray	Dark gray	Dark gray	Dark gray
Collaborative use of ICT					
Underlines text in a word processor					Light gray
Places a reaction on a forum				Light gray	Light gray
Adds an attachment to an email				Light gray	Dark gray
Forwards a file from the cloud			Light gray	Light gray	Dark gray
Navigates through emails		Light gray	Light gray	Light gray	Dark gray
Add the address of the recipient to an email		Light gray	Light gray	Dark gray	Dark gray
Identifies source of audio problems in video calls		Light gray	Light gray	Dark gray	Dark gray
Enlarges text in a word processor		Light gray	Dark gray	Dark gray	Dark gray
Disable the camera in video calls	Light gray	Dark gray	Dark gray	Dark gray	Dark gray
Shares an online video	Light gray	Dark gray	Dark gray	Dark gray	Dark gray
Creative use of ICT					
Selects a program for online collaboration		Light gray	Light gray	Dark gray	Dark gray
Chooses machine to make a math calculation		Light gray	Light gray	Dark gray	Dark gray
Chooses machine to make a phone call	Light gray	Light gray	Dark gray	Dark gray	Dark gray
Chooses machine to do a specific task	Light gray	Dark gray	Dark gray	Dark gray	Dark gray
Select a program for video conferences	Light gray	Dark gray	Dark gray	Dark gray	Dark gray
Selects a program for a presentation	Light gray	Dark gray	Dark gray	Dark gray	Dark gray
Recognises the icon for a webbrowser	Light gray	Dark gray	Dark gray	Dark gray	Dark gray

White represents a mastery level <50% (insufficient control). Light gray represents a mastery level between 50 and 80% (modorate control). Dark gray represents a mastery level above 80% (good control). For example, in the effective use of ICT, we see that in grades 4 and 5, only the questions about 'knowing where to type the web address in the web browser' and about 'knowing what kind of information can be found on the internet' were well mastered by the students. In contrast, the students in group 8 got most of the skills correct.

7 | DISCUSSION

The primary purpose of our study was to investigate if the ECC-ICT test is a valid and reliable test of primary school students' effective, collaborative, and creative use of ICT tools. This test of primary school students' use of ICT tools is a welcome addition to the gap created by literature that focuses mainly on secondary and higher education (Oh et al., 2021; Siddiq et al., 2016). Regarding testing ICT skills, existing digital literacy research has primarily focused on higher education (Norman & Skinner, 2006; Roque & Boot, 2018). In this study, we focused on primary education, where there is a growing need for teachers to assess their students' ICT skills,

We first defined the conditions for the effective use of ICT and selected the three conditions that focus on primary school students as actors. This resulted in three domains to be included in our ICT test: effective use of ICT, collaborative use of ICT, and creative use of ICT. Next, using a digital literacy framework with a wide array of learning objectives for primary school students (SLO, 2021), we translated the three conditions into 24 learning objectives covered by 34 test items. Nineteen items covered the effective use of ICT. Eleven Items covered the collaborative use of ICT. Seven items covered creative use of ICT. Twelve items covered more than one learning objective. Three items covered two domains. This procedure aimed to ensure the test's content validity. The cognitive validity of the test items was established through a series of three pilot tests, after which test items were refined if necessary.

The factor structure of the three domains of ICT use sufficiently fits the data, indicating that the ECC-ICT test consists of three subtests for the domains of effective, collaborative, and creative use of ICT (Prudon, 2015). Furthermore, the reliability analysis results indicated that all three subtests reliably measure students' ICT skills. The authors used knowledge of the theory and empirical research to postulate the relationship pattern in a three-factor approach a priori. Then, they tested the hypothesis statistically using a CFA. Hence, we theorise that the factor structure is pliable (Table 2) because the conceptual base can be interpreted from different perspectives. A holistic approach may favour the one-factor approach, while an SLO perspective may favour a two-factor approach. However, we maintain the three-concept structure because we developed the test from a conceptual framework that argues three factors. From this three-factor perspective, we can test that a CFA confirms this structure. Moreover, the factors we propose also coincide with the skills in a recent study by Van Laar et al. (2020) and UNESCO's broad overview of Digital literacy assessment (Reichert et al., 2023). Although the other factor structures are not significantly less of a fit, they do not have a conceptual base to be tested in this paper.

The difficulty and discriminatory power between grade levels show that for all three domains of ICT use, students in higher grade levels demonstrate higher ICT skills. This further indicates the tests' validity: as expected, the ICT skills measured by the test increase when children get older. This implies that in higher grade levels, students possess more advanced ICT skills. Conversely, students in the lower grades of primary school may have insufficient skills to use more complex digital learning tools. Teachers should bear this in mind when selecting ICT tools. The discriminatory power of the test for higher grades and difficulty levels is good for the effective and collaborative use of ICT, as shown in Table 7. The discriminatory power and difficulty level for the creative use of ICT can be improved in future iterations of the ECC-ICT test.

The reliability of the ECC-ICT was tested for the population described in this study (Dutch language, Primary school level). This is carefully generalisable for Dutch primary education because the eight schools' Social Economic Status (SES-WOA) range covers 0 and indicates a comparable SES to the average Duch primary school. Re-establishing reliability is advised for use in a different population (such as Higher Education). Performing a test–retest Alpha or Coefficient of Equivalence and Stability after a second run of our ECC-ICT test can give future research a greater insight into the long-term stability of the ECC-ICT test. The planning of the current study did not allow for the repeated measurement needed to make a statement regarding consistency over time.

An avenue for future research is using Effective ICT outside the current context (Dutch language, Primary school level). We expect an English version of the ECC-ICT test would perform the same because of the uniform definitions of digital literacy. However, we advise future researchers to tailor the English translations of our test items to their participants and re-check cognitive validity.

8 | CONCLUSION

The test analysis has shown that the ECC-ICT test is valid and reliable for the skills students need to Effectively, Collaboratively, and Creatively use ICT in Dutch primary education. Improvements can be made to the discriminatory power and difficulty levels of the Creative use of ICT. To this end, future researchers may develop additional test items that discriminate between the lower and higher grades. Reliability over time was also not part of this study and still needs to be researched to improve the test.

On a practical level, this paper presents a valid and reliable ECC-ICT test that educational practitioners can use to assess primary school students' effective, collaborative, and creative use of ICT tools. Administering the ECC-ICT test may help educational practitioners select tools that comply with their students' ICT skill levels. This is important to prevent students from overestimating their ICT skills (Aesaert et al., 2017; Prior et al., 2016; Rohatgi et al., 2016; Rubach & Lazarides, 2021; Siddiq et al., 2016). On the other hand, the test may provide practitioners with information on how much ICT training or support students need to use digital tools.

For educational theory, this paper provides a thorough insight into the development, validation, and reliability of our ECC-ICT test. Our procedure consisted of multiple rounds of cognitive validity testing, an internal consistency check, fitting different models and reporting outcomes in the most conservative method by calculating the coefficient McDonald's omega and accepting results above 60% explained variance. This test of the Effective, Collaborative, and Creative use of ICT is a welcome addition to educational theory in light of the seven skills (e.g. Collaboration digital skills, Creative digital skills, Problem-solving digital skills, Communication digital skills) by Van Laar et al. (2020) and the 4C (Constructive, Critical, Creativity, Collaborative) Learning Model on Students' Learning Outcomes by Supena et al. (2021).

AUTHOR CONTRIBUTIONS

Kevin Ackermans: Conceptualization; data curation; formal analysis; investigation; methodology; validation; writing – original draft; writing – review and editing. **Marjoke Bakker:** Investigation;

methodology; validation; writing – original draft. **Pierre Gorissen:** Funding acquisition; methodology; resources; supervision; writing – original draft; writing – review and editing. **Anne-Marieke van Loon:** Conceptualization; funding acquisition; resources; software; supervision. **Marijke Kral:** Conceptualization; funding acquisition; methodology; resources; supervision. **Gino Camp:** Conceptualization; funding acquisition; methodology; project administration; writing – original draft; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jcal.12924.

DATA AVAILABILITY STATEMENT

The datasets generated or analysed during the current study are available in the Open Science Framework repository under https://osf.io/5ecrf/.

ETHICS STATEMENT

Consent was obtained from all participants according to the HAN University of Applied Sciences procedures for informed consent (More information on the HAN informed consent procedure can be found at https://www.han.nl/onderzoek/onderzoek-bij-de-han/ethische-adviescommissie/). Data from the HAN University of Applied Sciences was shared with the Open University of the Netherlands for analysis. All applicable guidelines of the Open University of the Netherlands were followed to safeguard data management (more information on the OUNL data management procedure is available at the link https://www.ou.nl/en/ceto-forms-and-guidelines).

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