**Section 2:**
Teaching and assessing computing in the curriculum

# BCTt: Beginners Computational Thinking Test

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Raspberry Pi

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### Abstract

Computational thinking (CT) is a cognitive ability that is considered one of the core skills to be developed in order to successfully adapt to the future. Therefore, it is being included in school curricula all over the world and, gradually, at an earlier age. However, as the incorporation of CT learning in schools is recent, there is still no consensus on its exact definition or on how it should be assessed. Recent research suggests that systems of assessments should be used for this purpose, using various instruments, and thus covering the different CT dimensions. However, there is a lack of validated instruments for the assessment of CT, particularly for early ages. Taking as a reference a three-dimensional CT framework, based on a validated CT test, and aimed at early ages (five- to ten-year-old students), the Beginners Computational Thinking Test has been developed as a tool to be used within a system of assessments. This instrument has been designed, submitted to a content validation process through an expert judgement procedure, and administered to primary school students, obtaining very favourable results in terms of its reliability.


### Introduction

In a changing society, where technology and programming play a crucial role, students must be able to think critically and solve complex problems to adapt to the world in which they are expected to live in. Therefore, computational thinking (CT) is a core skill, necessary to adapt to the future and, consequently, it is an important area of education in many countries, some of them consider CT as a national program (Hsu, Chang, & Hung, 2018). In the early stages," in addition to reading, writing, and arithmetic, computational thinking should be added to every child's analytical ability" (Wing, 2006, p.33). However, there is still not enough research on how to teach and assess CT when it comes to young children (Rich et al., 2018).

Although CT is considered an essential skill and it should be learned at school, there is a lack of consensus in its definition and possible breakdown (Shute, Sun, & Asbell-Clarke, 2017). Abstraction, decomposition, algorithms, and debugging are the four CT components that arise most often in the literature and, furthermore, Shute et al. (2017) identify iteration and generalisation as two more components to add to CT skills. Brennan and Resnick (2012), developed the three-dimensional (3D) framework of CT which divides CT into three computational dimensions: (a) computational concepts, (b)

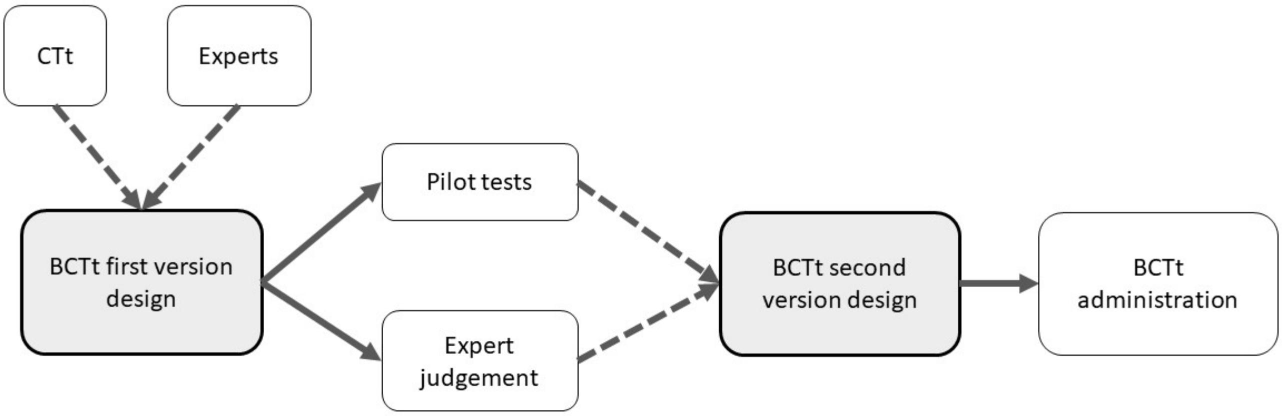


*Figure 1. Design and validation steps*

computational practices, and (c) computational perspectives (Brennan, Resnick, & MIT Media Lab, 2012).

With regard to the assessment of CT, Shuchi Grover proposes a system of assessments (Grover & Pea, 2015) that combines instruments of different types such as portfolio, survey, interview, and traditional test, and are thus able to cover all the CT dimensions. However, although efforts have been made in the last two decades in the development of assessment instruments, most of them are aimed at middle/high school students and are based on the analysis of programming projects carried out by students in specific environments such as Dr. Scratch that assess CT skills through the analysis of Scratch projects (Moreno-León & Robles, 2015). There are hardly any traditional tests that are independent of a programming environment and that can be used as pre-test and post-test instruments. Among them, the Computational Thinking Test (Román-González, Pérez-González, & Jiménez-Fernández, 2017) stands out, as it is designed under a psychometric approach and provides evidence about its reliability and content validity (Román González, 2015), but it is aimed at students between 10 and 16 years old. Based on the CTt, the Beginners Computational Thinking Test (BCTt) has been developed, aimed at younger students and, therefore, has required a deep adaptation in both form and content. Moreover, substantial improvements were added. A validation process was then carried out, including the administration of the test to students from 5 to 12 years of age from three different schools in Spain.

## Method

A first version of the test was designed, aimed at students from primary school stage. Based on the CTt, the test was adapted both in form and content to younger students, thus, several substantial changes were made. Then, the BCTt was pilot tested on small subsamples, and evaluated by experts in the field. Based on these preliminary results, changes were made to obtain a second version that was administered to students from 5 to 12 years old in three schools in Spain. The results obtained were analysed statistically. In Figure 1, the validation process is shown.

| Test questions | Computational concepts in BCTt | | | | | |
|---|---|---|---|---|---|---|
| | | Loops | | Conditionals | | |
| | 1. Sequences | 2. Simple loop | 3. Nested loop | 4. If-then | 5. If-then-else | 6. While |
| 1 - 6 | | | | | | |
| 7 - 11 | | | | | | |
| 12 - 18 | | | | | | |
| 19 - 20 | | | | | | |
| 21 - 22 | | | | | | |
| 23 - 25 | | | | | | |

*Table 1. BCTt computational concepts considered in each question*

## BCTt first version design

The test is aimed at young children who may not yet have acquired reading and writing skills, so the test was designed to include symbols and drawings that were self-explanatory. Aimed at older students, minimal helpful texts were included that redound to the symbol-based explanations. The symbolism is clear and aims to connect emotionally with the children so the learning process is enhanced (Căprioară, 2017) as it is a chick that must reach its mother.

The first version of the BCTt takes approximately 40 minutes to complete. It is divided into six sets of questions, and each set is related to one basic computational concept (Table 1). It is 25 questions long with three alternative responses per question.

There are two types of questions: canvas type — which is a "follow the line" design — and maze type or square matrix — in which there is a starting square and the students must reach the goal square, avoiding and/or picking up objects along the way, for example, another chick (Figure 2). The possible answers are sequences of movements represented by arrows, symbols, and numbers. Visual transitions were added

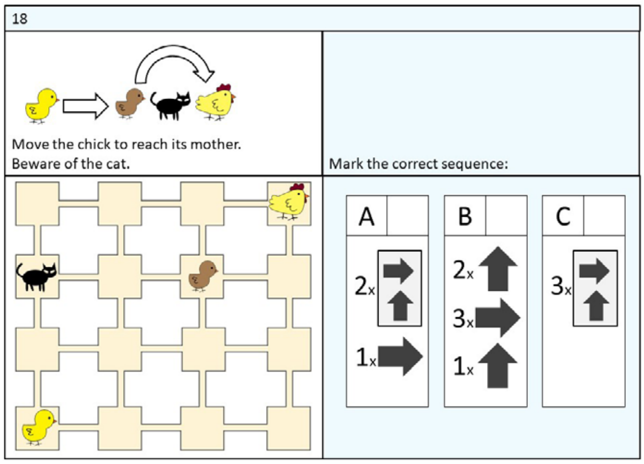


*Figure 2. BCTt first version question example (question number 18)*

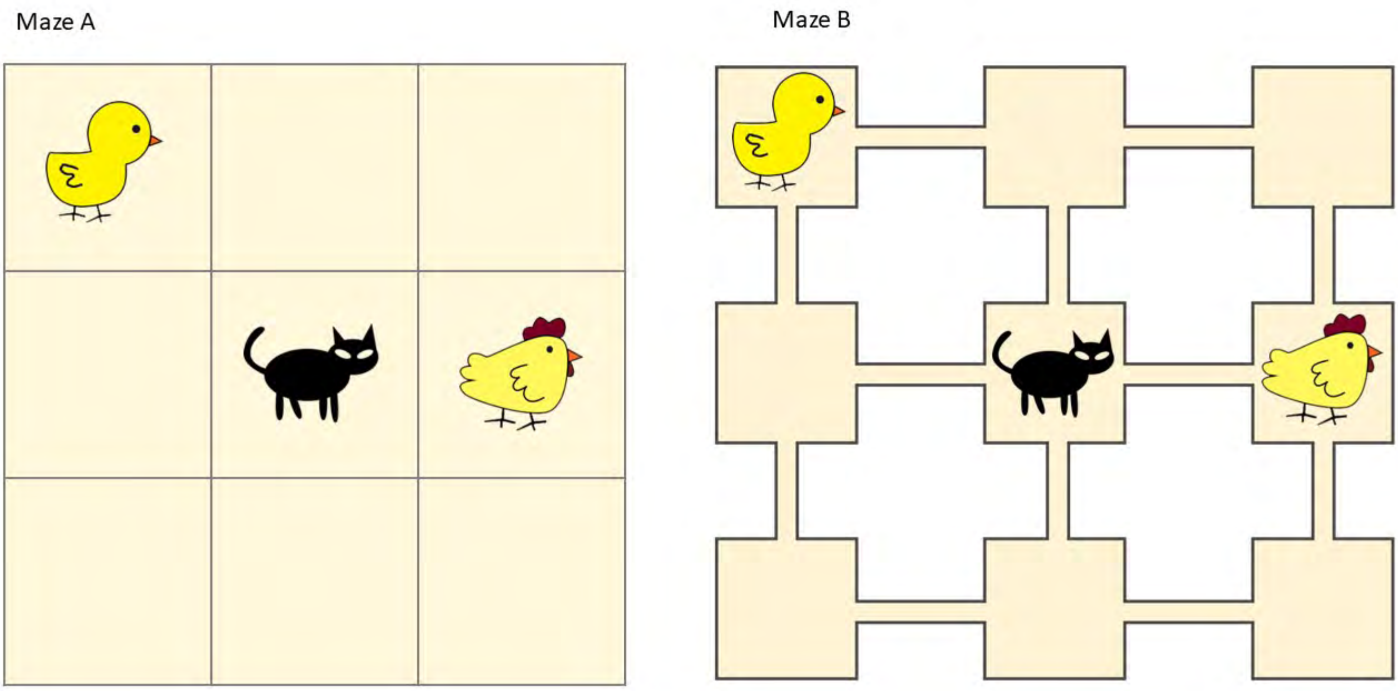


*Figure 3. Maze A: no transitions; Maze B: transitions are added between squares turning the maze into a state diagram*

in the maze layout (Figure 3), as a substantial improvement for young students, to help the visualisation of the step between one square and another, so that the maze becomes a state diagram which is a main programming element and it is proven to improve understanding of problems (Chen & Herbst, 2013; Durak & Saritepeci, 2018; Watanabe, 2015)

## Expert judgement procedure

The BCTt was submitted to an expert judgement procedure in which 45 experts (computer science professionals and schoolteachers) were consulted.

The experts were asked, via an online form consisting of 66 questions, about the adequacy of the questions in terms of its relevance to measure each of the different computational concepts included in the test. In addition, the experts were also asked several questions regarding length, symbolism used, and other issues. A special survey was also conducted on the transitions included in the maze-type questions. Finally, experts' comments and suggestions were collected.

Most of the experts considered the length of the test to be adequate, as well as the order of the questions, as their difficulty was perceived to be incremental throughout the test. The experts also considered that the test questions measured the computational concepts addressed and considered the nested loops as the most relevant concept of all (relevance to measure CT, Likert scale from 1 to 5: Sequences=3,66; Simple loops=3,82; Nested loops=4,14; If-then=3,95; If-then-else=4,15; While=4,05). As to whether the test as a whole assesses the computational

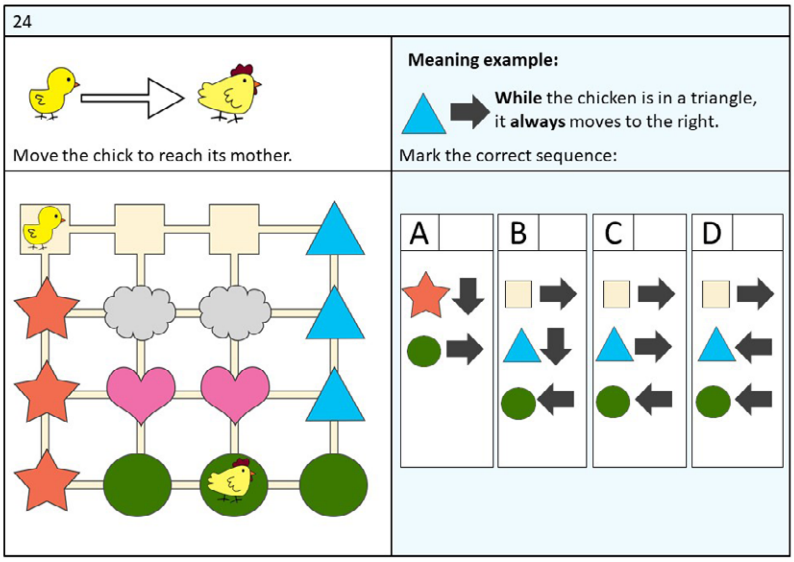


*Figure 4. BCTt question number 24*

concepts dimension of computational thinking in primary school students, 75.6% of the experts considered that completely or almost completely.

One of the substantial improvements of the BCTt was the inclusion of transitions in the maze questions. In this sense, the experts were very much in agreement with the improvement and considered that it would help younger students to better understand the answers in the test since, for example, the association between the arrows in the answers and a possible movement is easier, diagonal movements through the maze would be avoided or it is reflected more clearly when the chick has reached the goal square.

The comments and suggestions of the experts were very much considered. For example, some of their most frequent comments were about the need to first explain orally to the children the meaning of each set of questions, to add one more possible answer to each question, to replace the pickable elements (chicks) with other symbol that do not lead to confusion, to refine the questions concerning some computational concepts to get closer to their exact definition, etc.

Many of the experts considered the test too hard for such young children. This was refuted later when the test was administered to primary school students.

## BCTt second version design

Taking into account this feedback, the second version of the BCTt was designed with several modifications and additions. For example, one more answer alternative was added to each question, the statements of the questions were refined, the collectable elements were replaced by others, and the questions of some of the sets were reformulated to come closer to the computational concept formal definition.
One of the most remarkable changes was the reinforcement of the colours in the questions with a shapes symbolism, to allow students who are colour-blind to be able to take the test. This improvement makes the test suitable to be printed in black and white format (e.g. Figure 4).

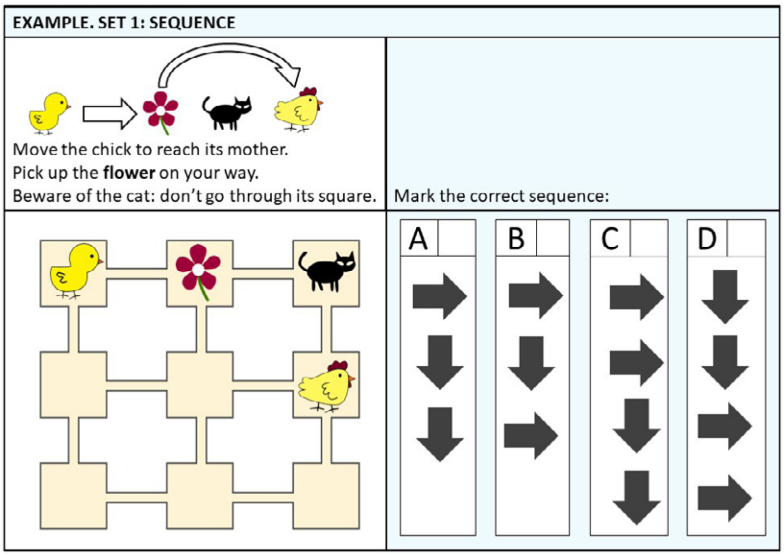


*Figure 5. BCTt action protocol, example for set 1: sequences*

In addition, an administration protocol was developed specifying that an oral explanation must be given to students prior to taking the test, with an explanatory example of each of the computational concepts addressed in the test. The protocol includes these examples and a guide on how to carry out the explanation (e.g. Figure 5).

| Educational stage | Grade | Identifier | BCTt variation 1 | BCTt variation 2 |
|---|---|---|---|---|
| 1st | 1 | A | A1: n=52 | |
| | 2 | B | B1: n=18 | B2: n=18 |
| 2nd | 4 | C | C1: n=54 | |
| | 4 | D | D1: n=28 | D2: n=28 |
| 3rd | 5 | E | E1: n=51 | |
| | 6 | F | F1: n=25 | F2: n=25 |

*Table 2. BCTt administration subsamples (n: number of students)*

| Grade | Subsample | BCTt variation | N | Mean | Std. Deviation | Levene's Test | t-test for Equality of Means | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Sig. | t | Sig. (2-tailed) |
| 2 | B1 | 1 | 18 | 16.778 | 2.487 | 0.841 | 3.042 | **0.005** |
| | B2 | 2 | 18 | 14.278 | 2.445 | | | |
| 4 | D1 | 1 | 28 | 21.357 | 2.438 | 0.113 | 0.122 | **0.904** |
| | D2 | 2 | 28 | 21.286 | 1.922 | | | |
| 6 | F1 | 1 | 25 | 21.720 | 2.622 | 0.185 | 0.499 | **0.620** |
| | F2 | 2 | 25 | 21.280 | 3.542 | | | |

*Table 3. Subsamples statistics and student t-test comparing BCTt variations (1: with transitions and 2: without transitions)*

## BCTt administration

The second version of the BCTt was administered to 5- to 12-year-old primary school students (n=299 ), following the action protocol, from three schools in Spain.
Two different variations of the second version of the BCTt were carried out, one including the transitions between the squares (variation 1), and the other without them (variation 2), in order to be able to compare the performance of the students with and without this aid. All tests were printed in black and white, so students who are colour-blind could take the test under the same conditions as the rest.

The sample of students was divided into several subsamples as shown in Table 2, considering the

| Subsample | | A1 | B1 | C1 | E1 | F1 |
|---|---|---|---|---|---|---|
| Grade | | 1 | 2 | 4 | 5 | 6 |
| N | | 52 | 18 | 54 | 51 | 25 |
| Mean | | **16.52** | **16.78** | **21.57** | **21.84** | **21.72** |
| Median | | 16.00 | 18.00 | 23.00 | 23.00 | 22.00 |
| Std. Deviation | | 3.31 | 2.49 | 3.04 | 2.61 | 2.62 |
| Variance | | 10.96 | 6.18 | 9.27 | 6.81 | 6.88 |
| Minimum | | 8.00 | 11.00 | 14.00 | 13.00 | 15.00 |
| Maximum | | 24.00 | 20.00 | 25.00 | 25.00 | 25.00 |
| Percentiles | 25 | 14.00 | 15.75 | 19.00 | 20.00 | 19.50 |
| | 50 | 16.00 | 18.00 | 23.00 | 23.00 | 22.00 |
| | 75 | 19.00 | 18.00 | 24.00 | 24.00 | 24.00 |

*Table 4. BCTt score statistics by grade*

age of the students, the variation of the test they would take, and the school group they belonged to. One of the subsamples (D1) was retested a second time five weeks later.

## Results and discussion

The main results of the BCTt validation process are presented below. The complete results are detailed in the paper presented at the EDUCON congress (Zapata-Cáceres, Martín-Barroso, & Román-González, 2020).

Transitions between squares in maze questions
The transitions between squares in the maze-type questions were intended to be a substantial improvement in the BCTt. To check this, test scores were compared between the BCTt variation 1 (with transitions) and BCTt variation 2 (without transitions). The results indicate that there is no significant difference in the test scores obtained in the samples of students from the fourth grade onwards, but there is a very significant difference between the scores of children in lower grades ($p=0.005<0.01$), indicating that this help is highly noticeable for younger children, but not for older ones.

## Descriptive statistics

A statistical analysis of the results obtained by all students in the BCTt, considering the total score of each student in the test as the sum of the correct answers (Table 4), shows in the first place that the overall average is high (19.92 points), which contradicts the opinion of the experts that the difficulty of the test is very high and, on the contrary, indicates that the test is too easy for older students, a ceiling effect is observed, and BCTt target could be students in the early stages of primary education.
Analysing the scores obtained in each of the computational concepts sets separately, in the questions dealing with nested loops and conditionals, students obtain low scores at all grades, while sequences and simple loops seem

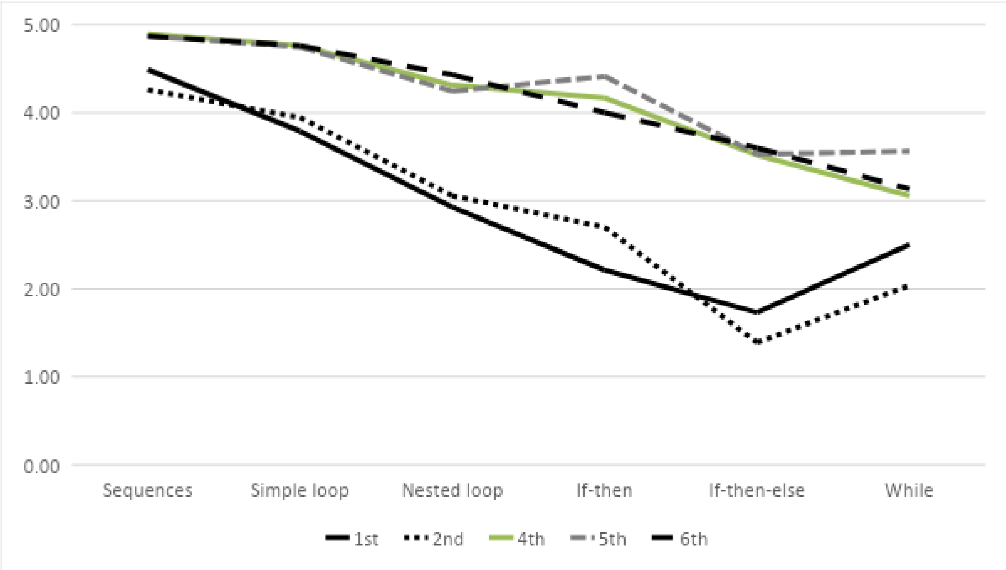


*Figure 6. Abscissa axis: computational concept by grade. Ordinate axes: BCTt question score, normalised from 0 to 5: 5 maximum score.*

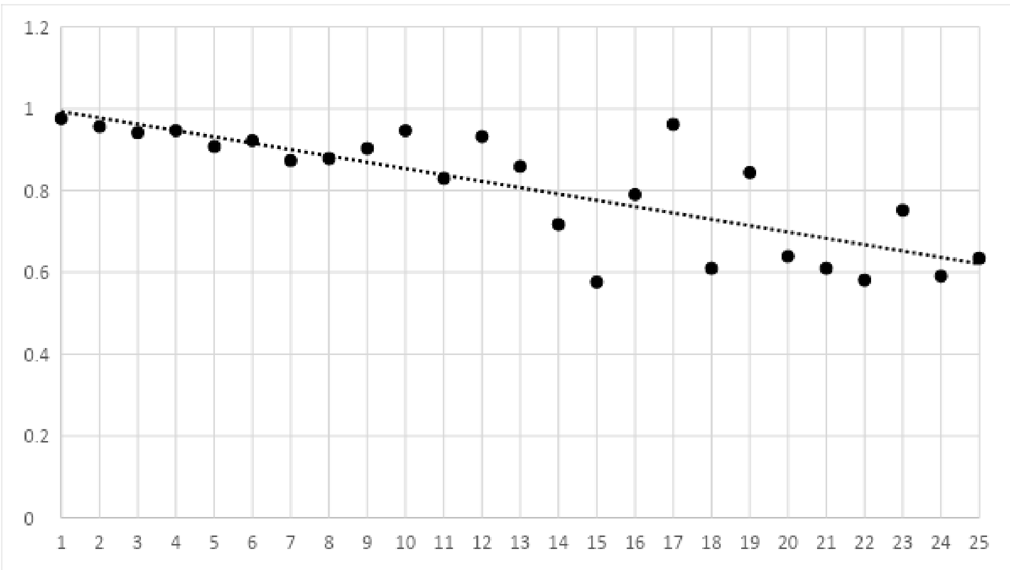


*Figure 7. Question difficulty index (ordinate axis) for each BCTt question (abscissas axis).*

too simple for high grades (Figure 6).

The difficulty index of each question confirms the increasing difficulty of the test anticipated by the experts, with the average index being very high (0.81) for the overall sample (Figure 7) and medium (0.70) for the first educational stage, in which also is balanced in terms of difficulty as its histogram is symmetric and fits the normal curve.

The histogram showing the distribution of the BCTt score along 1st and 2nd grades subsamples fits the normal curve and it is fairly symmetric, which suggests that the BCTt is balanced in terms of the difficulty of its questions for primary school 1st educational stage (Mean=16,59; Std. Dev.=3,104; N=70).

### Reliability

The BCTt showed a very good reliability considering all grades (Cronbach's Alpha: α=0.824), but when considering each educational stage separately, Cronbach's Alpha is lower the higher the grade (1st grade: α=0.833; 2nd grade: α=0.793; 4th grade: α=0.771; 5th grade: α=0.660; 6th grade: α=0.657). Therefore, the BCTt is more reliable in the early stages of primary education. In addition, Spearman's non-parametric test was used in a task and re-task method on the D1 sample (the BCTt test was administered twice under identical conditions with five weeks lapse) and showed a very strong positive correlation ($r_s$=0.93; $p<0.01$). Therefore, the reliability as stability was very high.

### Conclusions

The expert judgement procedure showed that the BCTt was adequate, both in design and content, being a balanced and incremental test in terms of difficulty. Furthermore, the concepts to be assessed seemed relevant in terms of the evaluation of computational thinking in its computational concepts dimension. The results of the administration of the test to primary education students confirm this, although it can be concluded that the test is aimed at students in the first grades (five to ten years old), as the first part of the test might be too easy for older students.

The test is balanced in difficulty, and in terms of reliability has proved to be very high, especially, again, for the early stages of primary education. The transitions added in the maze-type questions proved to be very significant as a positive aid for students in the first grades and had no effect (either positive or negative) on older students. Therefore, it is recommended to include transitions in this type of test questions in the future.

The BCTt has proven to be an instrument aimed at the early stages of primary education (five to ten years old), as an extension of the CTt (10 to 16 years old), independent of any environment, it focuses on 3D framework computational concepts, partially on computational practices, and ignores computational perspectives. It is recommended as a pre-test and post-test tool to be used within a "system of assessments" together with other instruments that assess other dimensions of CT (Román-González, Moreno-León, & Robles, 2019).

The BCTt in its second version is considered a good start for successive versions and improvements. As the first questions have proved to be too easy for high grades, and a ceiling effect has been observed, further adaptations of the test are currently being made for these groups and more difficult questions are being included. On the other hand, the lower age limit for taking the test has not been described and efforts are also currently being made in this regard. In addition, several translations and administrations of the BCTt are being carried out with other populations and countries.

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