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Understanding Teachers' Attitudes and Self-Assessment Towards Computational Thinking

María ZAPATA-CÁCERES[1*], Nardie FANCHAMPS[2], Ibrahim H. YETER[3], Pedro MARCELINO[4], Estefanía MARTÍN-BARROSO[1]
[1]Universidad Rey Juan Carlos, Spain
[2]Open University, Netherlands
[3]Nanyang Technological University, Singapore
[4]TreeTree2, Portugal

maria.zapata@urjc.es, nardie.fanchamps@ou.nl, ibrahim.yeter@nie.edu.sg, pedro.marcelino@treetree2.org, estefania.martin@urjc.es

ABSTRACT
Around the world, attention is being paid to computational thinking (CT) in education. Integration into school curricula places additional demands on teachers, promoting the skills and attitudes necessary to teach and integrate CT into education. Above all, it is important that teachers themselves are aware of the importance of CT and have a clear perception of its meaning. To enable an effective and developmentally-enhancing implementation of CT in education, teachers must have competence to teach CT, recognize from what age CT can be taught, and how to transfer the acquired CT skills to other school subjects and areas. Therefore, we collected and compared data among schoolteachers from four different countries to enlighten their attitudes towards CT, their opinion about opportunities and possibilities for integrating CT into education, and how and from what age CT can best be applied. Furthermore, by administering and evaluating the Beginners Computational Thinking Test (BCTt), teachers' perspectives regarding this validated instrument for the assessment of CT are analysed. From qualitative data obtained, we could deduce information about teachers' self-assessment of competence, confidence, and motivation to teach CT. From quantitative data collected by administering the BCTt to teachers, we obtained indications of teachers' mastery of CT competence. The data analysis confirmed our hypothesis that discrepancies exist between teachers' self-assessment and their actual CT competence. It can be argued that the findings from our research, therefore, provide valuable information for further shaping teachers' future professionalisation concerning CT.

KEYWORDS
Computational Thinking, teachers' perspectives, primary education, attitudes, self-assessment

1. INTRODUCTION
Understood as the human problem-solving process that uses decomposition and requires thinking at multiple levels of abstraction (Wing, 2006), Computational Thinking (CT) is widely recognised as essential for coping with today's technological society (Shute, Sun, & Asbell-Clarke, 2017). The increasing attention to the development of CT in primary education compels teachers to adjust their teaching repertoire accordingly. Teachers are increasingly aware of the development potential that CT can offer both for students and to enhance their own teaching. But regardless of the perceived added value for education, the question arises as to whether teachers have a sufficient grasp of what CT is, what skills it encompasses, and how it can be used in practice, especially for subjects unrelated to technology or programming. This is according to a purposeful application of CT so that students can benefit from its use in the most transversal and optimal way. Such an approach and implementation in education requires that teachers be thoroughly equipped to become familiar with the underlying principles and characteristics of CT, yet insufficient attention has been paid to fostering the skills and attitudes needed to teach the new content (Mannila, Nordén, & Pears, 2018; Nouri, Zhang, Mannila, & Norén, 2020), and which type of guidance is most effective for teachers (Fanchamps, Specht, Hennissen, & Slangen, 2020). Moreover, teachers from different countries perceive that CT can foster a connection between different disciplines and provide an opportunity to support teachers' pedagogical practices (Diordieva, Yeter, & Smith, 2019). However, more research is needed regarding how CT can be integrated into a curriculum, on the pedagogical possibilities that CT can offer teachers, and on the required areas of professional development and teacher training.

Evidence suggests that teachers' understanding, prior knowledge requirements, pedagogical skills, knowledge of related technology, and self-confidence in teaching CT can be improved in a relatively short period of time through targeted professional training (Bower et al., 2017). Increasing student exposure to CT in schools is complex, requiring systemic change, teacher commitment, and the development of meaningful resources (Barr, Harrison, & Conery, 2011). With educational changes, teachers inevitably face such challenges. If teachers have inaccurate perceptions of CT, this will directly influence how they teach this area (Milton, Rohl, & House, 2007). Researchers have made strong connections between teacher efficacy and teacher behaviours that foster student achievement (Goddard, Hoy, & Hoy, 2000). If teachers do not feel effective in teaching CT, students may have negative learning experiences (Israel, Pearson, Tapia, Wherfel, & Reese, 2015).

The question is, however, whether and to what extent primary school teachers currently have sufficient insight into these underlying conditions. It is therefore particularly remarkable that much of the research conducted into the

possibilities and effects of CT focuses on students, but that there is still too little focus on the perception and awareness of the teachers. Differences in the situation within national curricula and between different countries also play a major role. Moreover, it can be stated that CT is the focus of attention in some countries, while this is much less the case in others. It is therefore valuable to know teachers' perspectives on CT for different countries. In order to make a representative comparison, we selected countries with different starting situations or levels in terms of their approach to education and research on CT (Saqr, Ng, Oyelere, & Tedre, 2021): Portugal, with a low level; the Netherlands, with an intermediate level; and Spain, with a high level. On the other hand, we have selected Singapore, as a non-European case with an intermediate level, given that the research carried out by Dagienė *et al.* on a total of 52 countries reveals that only 21% of the countries consulted include CT development in the school curriculum and of these, 91% belong to Europe (Dagienė, Jevsikova, Stupurienė, & Juškevičienė, 2021). By comparing the findings, indications can be obtained on the focus and underlying rationale for the importance of CT for each country. This comparison may subsequently contribute to the further definition and operationalisation of CT in education.

Regarding educational frameworks for teaching CT in primary education, one of the most cited in the literature and most empirically applied is the 3D framework (Brennan & Resnick, 2012). This framework divides CT into three dimensions: 1) computational concepts (concepts that programmers use); 2) computational practices (problem-solving practices that are produced in the programming process); and 3) computational perspectives (perspectives that designers form about themselves and the world around them). Besides, due to the recent introduction of CT in school curricula at an international level, there are still few validated instruments for the assessment of CT competence, particularly at early ages, Tang et al. identified 4 possible ways of assessing CT: traditional test, portfolio, questionnaires, and interviews (Tang, Yin, Lin, Hadad, & Zhai, 2020). In order to be able to analyse CT skills without relying on any particular learning environment, it is necessary to use a traditional test-type assessment tool such as the Beginner's Computational Thinking Test (BCTt), which is one of the few existing assessment instruments that have been validated in terms of reliability, under a psychometric approach, for early childhood and primary school students (Zapata-Cáceres María, Martín-Barroso, & Román-González, Apr 2021). The BCTt focuses on computational concepts and, partially, on computational practices, and has been included as an assessment instrument to be evaluated by teachers, as well as an element to assess teachers' actual skill competence in CT.

Qualitative and quantitative data were used to assess, from the teachers' perspective, aspects such as the importance of CT in the curriculum of each country, the training teachers receive in this area, the involvement of teachers in schools in different subjects, and the ages at which attention is paid to CT in schools. Data were also collected on teachers' perceptions of CT, their confidence and motivation to teach CT in their classrooms, and their competence self-assessment. Finally, we assessed the teachers' CT competence using the BCTt.

Considering previous rationale, our research question is: Are there specific differences between countries in terms of motivation, self-perception, knowledge, information, and competence in CT; as well as discrepancies in teachers' perception and actual competence in CT?

2. METHOD

To conduct the research, we designed an online survey that was administered to teachers (N = 328). Besides, the BCTt, targeted to children from 5 to 9 years old, was also included for teachers to complete. This approach has been chosen as such because, apart from collecting teachers' perceptions on CT, we also want to give them the opportunity to form an opinion regarding this validated assessment instrument and, at the same time, reflect on their own skills by completing the test.

The participants in this study were active pre-school and primary school teachers from 4 different countries: The Netherlands, Portugal, Spain, and Singapore; who were asked questions about the importance of CT, the methodology and pedagogy for developing this skill, and their self-perception of this competence. In a first approach, in which questions were asked about the level of teachers' knowledge of CT according to the subjects taught, 83 teachers from Spain, 54 from Portugal, 42 from the Netherlands, and 149 from Singapore took part. In a second approach, in which in-depth data were collected, 83 teachers from Spain, 54 from Portugal, and 42 from the Netherlands participated. This second phase was divided into the following blocks: 1) demographic data; 2) teachers' perspectives on the importance of CT and how to develop it at an early stage; 3) teachers' perspectives on how and when CT should be taught; 4) teachers' perspectives on how and at what age CT is taught in each school; 5) teachers' perspectives on how and at what age CT is taught in each country; 6) teachers' professional development and training in CT; 7) test administration (BCTt); 8) teachers' opinions and perceptions on the BCTt, and; 9) suggestions and comments. Answers are collected as options to select, Likert scales (1-5), or open text, depending on the nature of the question.

Finally, teachers answered the BCTt and were asked for their feedback. In addition, their test scores were collected for comparison with the teachers' self-perception of this competence. In this phase of the study, 83 teachers from Spain, 54 from Portugal, and 32 from the Netherlands participated. Moreover, the 149 teachers from Singapore were asked about their understanding of CT.

3. RESULTS AND DISCUSSION

In terms of demographic data, the teachers in the Spanish sample are younger than those in the other countries, with 70% being under 40 years of age, while in the Netherlands, only 40.5% are under 40 years of age and in Portugal this percentage drops to 13%. For this reason, in Portugal, more than 90% of teachers have more than ten years of study, while in Spain and Portugal only about

50% of teachers are so experienced. On the other hand, the percentage of women is higher in all samples, being the highest in the Netherlands (76%). All teachers are primary school teachers, and only in Spain are there also preschool teachers in the sample (13.1%).

As for the subjects taught by teachers, in Portugal, 68.5% teach computer science, technology, or programming, compared to 35% in Spain, 19% of the sample in the Netherlands (where 73.8% are classroom teachers), and none in the Singapore sample, where teachers were chosen to teach subjects not a priori related to the teaching of CT. It is noteworthy that 16.7% of teachers in the Netherlands sample teach children with special needs, compared to 11.1% in Portugal, 6% in Spain, and none in Singapore.

In addition to the greater teaching experience reported by Portuguese teachers, they are also perceived to have more knowledge, since 68.5% of the sample reported high or very high knowledge and skills in CT and only 9.3% low or very low knowledge (Likert scale 1 to 5). However, in Spain, only 29.7% report a high or very high level and an unexpected 32.1% a low or very low level, since they are much younger teachers and CT is a competence that is only recently being implemented in schools. In The Netherlands, the results are similar to Spain, with 21.4% of teachers with low or very low self-perceived knowledge of CT, and only 31% of teachers with a high or very high level (Likert scale from 1 to 5). As shown in Figure 1, it is noteworthy that in the Singapore sample, only 16.1% of the teachers who teach subjects that are not related to programming or technology indicate a high or very high level of knowledge, compared to 60.4% who have low or very low knowledge of CT, with 59 teachers out of the 149 sampled reporting no knowledge of CT at all.

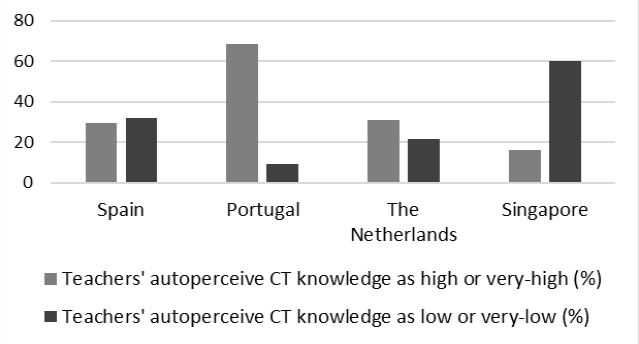

Figure 1. Teachers' auto perception of their CT skills.

In all samples, all teachers indicate that CT is important for students to be equipped to cope with the society of the future, and more than 80% consider it necessary for this competence to be integrated into the school curricula. However, Portuguese teachers are the most aware of the importance of incorporating this competence into the curriculum, with 94.4% considering it to be of great importance and more than 90% considering it to be related to student self-efficacy, compared to only 70% (approximately) of teachers in the Netherlands and Spain. In addition, more than 75% of the full sample and all teachers of children with special needs indicate that the CT can be very positive for these children.

A large majority of over 90% in Portugal and Spain are aware that CT can improve students' skills in other non-technology subjects, while in the Netherlands 76.2% are of this opinion and most teachers in Singapore believe that CT is only related to computer science. However, in Portugal and Spain, most teachers consider CT as a pedagogical mechanism and not only as an end in itself and understand that it can be taught independently of computer science as a cross-curricular competence. Moreover, also in Spain and Portugal, they advocate more teacher training in CT and teaching this competence in all schools (more than 90% of respondents approximately), compared to less than 70% of teachers of the Netherlands.

Regarding the second part of the questionnaire about the teachers' perspectives on how and when CT should be taught, the majority of teachers in all samples indicate that it should be taught later than age 4, and more than half of them think that it should be taught from age 7. Only around 17% believe that it should be taught before the age of 4, when it has been proven that it is better to start developing this competence as early as possible, similar to when learning a language (Mozelius & Öberg, 2017; Soosai Raj, Ketsuriyonk, Patel, & Halverson, 2018). Similarly, when teachers are asked whether CT should be taught in early childhood education, less than 60% say yes, and even in the Netherlands, only an unexpected 19% say it should be taught at this stage, when the integration of CT into the school curricula from the early childhood stage has long been promoted internationally. Moreover, teachers in all countries consulted believe that there are no gender differences in the learning of CT. However, previous research shows that girls are better at solving complex problems and boys at solving medium-difficulty problems (Eguiluz, Guenaga, Garaizar, & Olivares-Rodriguez, 2017; Guenaga, Eguíluz, Garaizar, & Gibaja, 2021), and there are also differences in the dispositions for the development of CT between boys and girls (Zapata-Cáceres & Martín-Barroso, 2021).

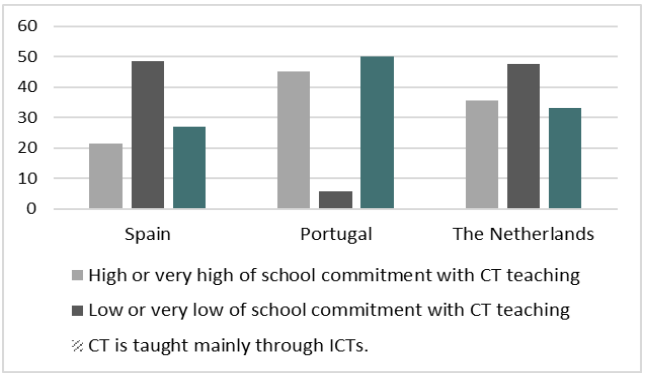

Figure 2. Schools' commitment to CT teaching.

Regarding block 3, teachers' perspectives on how and when computational thinking should be taught, there are large differences between the Portuguese sample and the rest. Portuguese schools are much more committed to the integration of CT in their classrooms and it is taught mainly through ICT-related tools (see Figure 2). However, teachers are not sufficiently informed as can be seen in Figure 3. Again Portugal has the highest percentage of schools, almost half, that include CT in their school

curricula, while in The Netherlands, more than half of the schools do not include it, and in all cases, there is a worrying percentage of teachers who do not know whether or not CT is included in the school curricula. In fact, teachers in all countries report a lack of knowledge and training on CT, materials, and resources.

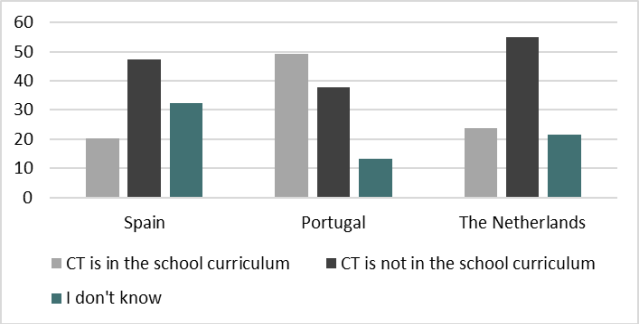

Figure 3. CT inclusion in school curricula.

When asked about how and at what age CT is taught in each country, teachers do not know how to answer the questions adequately because they lack information on the subject. In Spain and Portugal, the vast majority consider that, in their countries, CT is taught mainly from the age of 12 onwards, and that it is not a priority competence in education at national level. They also point to a lack of equipment, training, and resources for teaching CT, highlighting the lack of practicality of the initiatives that do take place. In the Netherlands, most teachers are aware that CT is taught at state level, but they also point to the lack of training (almost none), equipment, and time available to teach this competence. They feel that perhaps more attention should be paid to traditional subjects such as mathematics or language, rather than to transversal competencies such as CT.

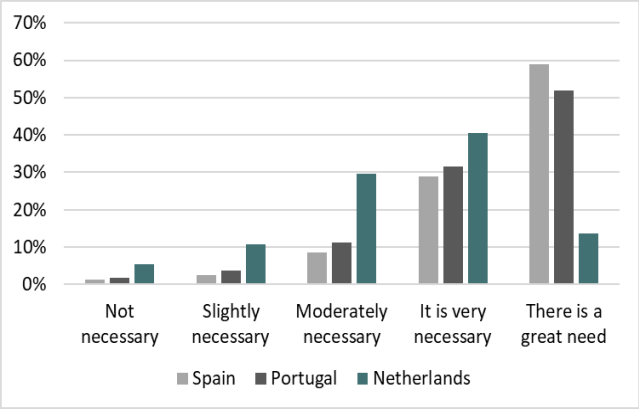

Figure 4. The need to include CT in the school curricula.

Although there are activities for teacher development and general training, few focus on CT, which is undesirable considering that it is a recent competence, and all educators need to be trained in it. In Spain, 44% of the respondents, and 35.7% in the Netherlands, have not received any CT training. Portugal is the country that is paying the most attention to this type of training, and only 18.5 % of teachers have not received any training. It is noteworthy that, although there is little training in CT in the Netherlands, the teachers surveyed are the least likely to perceive the need for such training (see Figure 4), with only 14% of teachers considering it to be a great priority.

Table 1. Correlation BCTt and Auto-assessment (AA).

		AA	BCTt total average
Auto assessment	Pearson Correlation	1	,241**
	Sig. (2-tailed)		0,002
	Sum of Squares and Cross-products	196,059	6,818
	Covariance	1,167	0,041
	N	169	169
BCTt total average	Pearson Correlation	,241**	1
	Sig. (2-tailed)	0,002	
	Sum of Squares and Cross-products	6,818	4,080
	Covariance	0,041	0,024
	N	169	169

***. Correlation is significant at the 0.01 level (2-tailed).*

In the third phase of the study, the BCTt was administered to teachers in Spain, Portugal, and the Netherlands. There is a significant correlation (Pearson's $r = 1.00$) between teachers' reported knowledge of CT (Mean = 3.25 on a Likert scale from 1 to 5), and the test score, as can be seen in Table 1, indicating that they are aware of their level of competence. It is noteworthy that 76.3% of teachers declare medium, high, or very high competence in CT. Furthermore, the ANOVA test shows no significant difference in test performance between the different countries ($F(2.166) = 1.958$, $p = 0.144$). Thus, teachers obtain similar results although, as seen above, there are large differences between countries in terms of the training received, the profile of the teachers, or their age and teaching experience.

Table 2. BCTt Average Scores by Country.

	Mean	*n*	*Std. Dev.*	*Min*	*Max*	*Sum*
Netherlands	21,75	32	3,733	7	25	696
Portugal	22,07	54	3,947	5	25	1192
Spain	20,80	83	3,879	6	25	1726
Total	21,38	169	3,896	5	25	3614

Table 3. BCTt total averages Gender

	Quantity				
	n	*M*	*sd*	*Median*	*Range*
BCTt Men	64	0.89	0.141	0.96	0.28-1.00
BCTt Woman	105	0.83	0.161	0.88	0.20-1.00

Note. n = respondents; M = average; sd = standard deviation

However, their overall performance on the test, i.e., their overall competence in the concepts associated with CT, is below what is expected and does not match their perceived competence, as the mean scores (considering the BCTt score as the sum of correct answers across the 25 test items) are lower than those obtained by primary school students in another research (Zapata-Caceres et al., 2020). It is remarkable that students aged 7 to 10 obtain an average score of 21.57 out of 25 on the test, which is very similar and even higher than the average score of 21.38 out of 25 obtained by teachers (see Table 2), especially in Spain, where teachers perform almost two points lower than primary school students. Although the samples are not statistically comparable, as the test is aimed at primary school students and is not validated to assess teachers' CT

competence (Zapata-Caceres et al., 2020), it would be expected and desirable that teachers would perform much better in the CT test than students, given that the test assesses a beginner level in CT. Maximum or close to maximum scores would be expected, since, in order to teach a subject, it is necessary to master it. The data also show large differences in test scores between teachers (*sd* = 3.896), some scoring unacceptably low (see Table 2). On the other hand, the data also indicate a significant difference (t (167) = 2.54; p = 0.015; CI [0.01-0.11]) between the performance of men and women, with the latter showing a worse performance (see Table 3).

Finally, teachers gave their opinion on the BCTt and made general comments on CT and its inclusion in the school curricula. In general, teachers found the test too difficult for primary school children, in fact, many teachers felt that children would not even be able to understand the questions at all. However, research suggests otherwise, and the test shows very high reliability for children aged 4 to 7 years, it was even necessary to create a more difficult test for children aged 7 to 10 years (El-Hamamsy et al., 2022) as a ceiling effect was observed. This indicates a discrepancy between the CT skills that teachers believe students have at an early age, and the level that children can actually achieve. Several teachers indicated that an oral explanation to the children would be needed before taking the test, which is indicated in the BCTt protocol.

In addition, many of the teachers do not understand exactly what CT is, especially teachers who do not have a computer-related background. For example, in the case of Singapore, where the entire sample is made up of teachers who do not teach computer science, technology, or programming, teachers are unable to define CT and some even indicate that they do not know the term. Those who do define it, relate it to algorithmics or computation, but do not find the implication that CT may have for the subjects these teachers teach.

4. CONCLUSIONS

Although most teachers have a high self-perception of their competence in CT, their actual skills in terms of the computational concepts related to CT do not match this self-perception, being much lower than expected, nor does their knowledge of the methodology to be applied or the age at which to start developing CT. One of the problems detected is that teachers largely underestimate children's ability in this competence at an early age and start teaching CT usually much later than would be advisable (Román-González, Pérez-González, & Jiménez-Fernández, 2017). Thus, CT teaching is mostly concentrated in students older than 7 years in all samples, which shows that not only teachers are not aware that CT teaching should start in early childhood education (especially in Portugal, the Netherlands and Singapore), but also that CT teaching is not implemented in schools until later. On the other hand, teachers who are not related to technology, computer science or programming have little information about CT and do not know how they could develop this competence in their subjects without using electronic devices, or how its development positively affects other areas away from computer science or technology.

As this competence is only recently being included in school curricula internationally, most teachers are not informed about its integration in their schools, nor do they know whether it is being taught in other schools or at the national level. The Netherlands teachers are the most informed about it, but surprisingly, they are the least willing to provide activities to develop CT.

Although there is training on CT, it is clearly not sufficient and should include: a) information on the appropriate starting age; b) competences that can be achieved by children at each age as well as training on the existing differences in terms of gender in developing CT, as well as in children with special needs; c) training on the transversality of CT, i.e. how to develop CT in different subjects, especially those not related to IT or technology (especially in Singapore), and without using electronic devices, i.e. CT unplugged (Brackmann et al., 2017; Zapata-Ros, 2019), especially in Singapore and Portugal; d) raising awareness of the importance of CT so that it is not seen as a waste of time and is perceived as a competence that positively influences the understanding and development of other subjects, especially in the Netherlands; e) training in CT competence, so that teachers are highly skilled and understand what CT is and the underlying computational concepts at an appropriate level to enable them to teach this competence to their students (especially in Spain); f) training in the incorporation of CT in both a transversal and a specific way, at school level and at state level in each country (especially in Spain, Portugal and Singapore).

In our opinion, the inclusion of training at all the levels described above, where shortcomings have been detected, is important and would improve both the quality and the content of the teaching of this competence in schools, adapting it to each age and characteristics of the students. This improvement would have a transversal impact on all subjects since the development of CT has a positive impact on other areas of knowledge.

It would be advisable to repeat this study in other populations since there are differences between countries regarding teachers' perception of CT. For example, in Singapore, more training is needed than in the rest of the countries regarding transversality of CT. In the Netherlands, there is a need for greater awareness of the relevance of CT. In Spain, more training is needed to understand the concepts around CT. In Portugal, although the sample was composed of older teachers than the rest of the samples, they are the ones who perceive more CT as a skill that needs to be developed to cope with 21st century society, but more training is needed on the transversality of CT and its teaching in non-technological subjects.

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6. ETHICAL STANDARDS

The Ethical research board (cETO) of the Open University of the Netherlands estimates this research is in line with the rules and regulations and the ethical codes for research in Human Subjects (reference: U202111122/ManonQuint).

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