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# Fostering computational thinking through digital storytelling: a distinctive approach to promoting computational thinking skills of pre-service teachers

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**Abstract**
The present study illustrates digital storytelling (DS) as an open-ended learning environment, which is one of the ways of preparing pre-service teachers (PST) to practice computational thinking (CT) in their future teaching. An 8-week teacher training program was organized and presented. The study aims to investigate the program's impact on the PST's CT skills, CT-integrated DS design skills, and their perspectives. A study group of fifty-two second-year PSTs took part in the Instructional Technologies course. An embedded mixed-method design was used. The CT scale was used as a pre-test and post-test to examine the development of the PST's CT skills for quantitative data collection. The qualitative data comprise the CT-integrated DS projects developed by the PST during the training and the reflection reports they wrote at the end of the training. The paired samples t-test was used in the analysis of quantitative data. The DS projects were evaluated using the rubrics with the story/storyboard, DS, and CT skills dimensions. Reflection reports were analyzed using thematic analysis. The findings revealed a significant improvement in the PST's CT skills after the training program. The qualitative findings show the PST's perspectives on CT definitions, the perceived benefits of CT and DS, and the use of DS to promote CT. The qualitative findings also present evidence for the CT-integrated DS design skills of the PST. Therefore, the study presents early findings showing that CT components could be integrated with DS and used in teacher education effectively without any pressure to use programming tools. The study also shows how DS is gradually integrated with the CT components as a suggestion for future studies.

**Keywords** Teacher education · Computational thinking · Digital storytelling · Open-ended learning environment · Pre-service teachers

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## 1 Introduction

Computational thinking (CT) is supposed to be "a fundamental skill for everyone" (Wing, 2006, p. 33). CT involves using methods, practices, and concepts of computer science to solve problems in any discipline (Kazimoglu et al., 2012). CT is regarded as a critical skill that has taken on a more vital role in education of late; furthermore, CT is applicable in many other fields in which problem-solving skills are fundamental (Lu et al., 2022). CT skills are significant among those approaches that enable students to solve problems in disciplines as varied as science, humanities, and mathematics (Adler & Kim, 2018; Bundy, 2007; Weintrop et al., 2016; Wing, 2006).

Wing (2006) proposes teaching CT as a core skill within the school curriculum to allow K-12 students to comprehend abstract, algorithmic, and logical thinking and to solve challenging, open-ended problems. Besides, integrating CT into the school curriculum in K-12 education supports students' digital competencies and 21st-century skills (problem-solving skills, collaborative skills, etc.) in addition to CT skills (Nouri et al., 2020). Barr and Stephenson's (2011) study on how CT can be integrated across disciplines, including computer science, mathematics, and science education, provides essential clues for integrating CT. Nonetheless, CT-related activities are mainly added to the school curriculum as elective courses or organized as extra-curricular practices (Bocconi et al., 2016; Duncan & Bell, 2015; Heintz, Mannila, & Färnqvist, 2016; Rubinstein & Chor, 2014; Ruthmann et al., 2010; Vlahu-Gjorgievska, Videnovik, & Trajkovik, 2018). One of the key factors contributing to this is the readiness of teachers to embrace and integrate CT into their teaching. Currently, teacher education programs do not include compulsory content on teaching CT.

The role of teachers is pivotal in the integration of CT into the process of teaching and learning (Fessakis & Prantsoudi, 2019). However, integrating CT is a new and challenging topic for teachers. Teachers need extensive professional development opportunities to integrate CT into school education at the K-12 level (Kong et al., 2023). For students to cultivate CT skills throughout grades K-12, it is essential for teachers to receive adequate education on CT and learn how to seamlessly incorporate it into their classes (Yadav et al., 2014). The design of teacher education programs is critical to effectively embedding CT into theory and practice, and it should be designed in a contextualized manner and made relevant to the prescribed curriculum (Butler & Leahy, 2021). Also, CT emerges as an integral component of teacher education, particularly in the context of digital competencies (Tankız & Atman Uslu, 2023). There is a correlation between pre-service teachers' (PST) digital competence and CT skills; PST who have a more excellent perception of their digital competence obtain a higher score in their CT. Those PST who score low in CT seem to demonstrate a weaker understanding of their digital abilities (Esteve-Mon et al., 2020). Similarly, a significant number of computer science teachers lack a robust conceptual understanding of CT, and there is a need for clarification among some regarding the precise essence of CT (Alfayez & Lambert, 2019).

This study takes the position that CT should be integrated into subject areas beyond computer science. Tengler et al., (2021a, 2021b) suggest designing and developing storytelling scenarios to integrate CT into the school curriculum, as well as supporting

teacher education in this regard. Some recent research shows that integrating CT into digital storytelling (DS) improves students' learning, motivation, and performance (e.g., Parsazadeh et al., 2021) and enables students to become creative storytellers (e.g., Vinayakumar et al., 2018). As per Robin (2008), DS has the potential to enhance various skills, including digital, global, technology, visual, and information literacy—encompassing the ability to locate, assess, and synthesize information. Similarly, PST view the incorporation of DS in the classroom as advantageous for fostering motivation and engagement among learners, encouraging self-expression, and facilitating collaborative learning while acquiring a range of skills (Tiba et al., 2015). Despite the insufficient number of studies, some researchers have recently focused on how DS can be used in promoting CT (e.g., Hoić-Božić et al., 2019; Parsazadeh et al., 2021; Tengler et al., 2021a, b; Vinayakumar, Soman, & Menon, 2018). The degree of need PSTs have for CT teaching must be analyzed in tandem with how to best integrate CT into various disciplines. Addressing PST' requirements for CT instruction and exploring the CT integration into diverse disciplines, this research shares the outcomes of teacher training designed to enhance the CT skills and CT teaching capabilities of PST by incorporating DS. At the end of the research, how DS is gradually integrated with the CT components is presented as a suggestion for future studies.

## 2 Conceptual framework

### 2.1 Computational Thinking (CT)

The concept of CT became widespread with the article published by Wing, one of the computer science researchers, in 2006. Before this, Papert (1980, 1996) examined CT with learning mathematics and other subjects. Papert continued his efforts to develop children's procedural thinking skills with LOGO programming. In the twenty-first century, Wing's (2006) work led to an explosion in integrating ICT into K-12 education.

According to Wing (2006), CT utilizes fundamental concepts from computer science to address problems, develop systems, and articulate them comprehensibly to human thinking. CT is fundamental in performing a complex task and selecting appropriate representations for the problem (Wing, 2006). It is beyond using software and hardware products. Moreover, it is a critical approach for solving problems, managing daily life, and communicating and interacting with others. According to Barr et al. (2011), CT is a process for addressing problems that includes the capacity for students to formulate solutions, arrange and analyze data logically, convey data in an abstract way using simulations and models, and automate algorithmic thinking solutions. One of the student standards endorsed by the International Society for Technology in Education (ISTE, 2016) emphasizes that students should possess CT skills.

CT researchers investigate CT implementations from different perspectives, such as learner level, teaching strategies, and learning effectiveness (Hsu et al., 2018). They are committed to continually researching new methods of improving student CT skills by integrating CT into the curriculum (Bower et al., 2017). DS, among these innovative methods, is one of the pedagogical implementations improving

students' CT skills and is employed in various ways and different subjects to help students develop multiple learning skills and abilities at all educational levels (Hsu et al., 2018; Kordaki & Kakavas, 2017; Vinayakumar et al., 2018; Yadav et al., 2014). Hsu et al. (2018) identified storytelling as one of the 16 learning strategies that support CT, along with project-based, design-based and problem-based learning, universal design for education, and systematic computational strategy, in a systematic review study that examined 120 articles. CT contributes to the learning process through DS. As an open-ended learning environment, DS provides a context and opportunities that foster active participation in CT.

Open-ended learning environments facilitate the representation, manipulation, and exploration of complex concepts, utilizing technological tools and resources to bolster learning objectives and construct knowledge (Hannafin et al., 1994, 1999). These environments are designed to promote cognitive flexibility in learners, fostering the development of transferable skills across various situations and enhancing sophisticated problem-solving skills (Jacobson & Spiro, 1995). Additionally, these settings ensure active student engagement in authentic problem-solving, including the formulation, testing, and revision of hypotheses, exploration and manipulation of concepts, and the provision of opportunities for reflection on acquired knowledge (Land, 2000). In these learning environments that encourage "learning by doing," the enrichment of learners' experiences and the reinforcement of learning are achieved by leveraging technological tools and resources to aid in achieving learning objectives and constructing knowledge (Hannafin, 1995; Land, 2000). Open-ended learning environments take advantage of the opportunities technology offers to create settings where complicated concepts can be manipulated, represented, and explored (Hannafin et al., 1999).

### 2.2 Digital Storytelling (DS) as an open-ended learning environment

The literature review shows that games (e.g., Berland & Lee, 2011; Rose et al., 2020), educational robotics (e.g., Chevalier et al., 2020; Kert et al., 2020), and programming (e.g., Chen et al., 2017; Duncan, & Bell, 2015) have gained prominence in developing CT skills. This study used DS as an open-ended learning environment to support CT skills. DS aids learners by making abstract concepts more tangible, transforming conceptual content into a more comprehensible format, and delivering the content in an engaging and interesting manner.

Additionally, every stage of DS supports PST's research, organization technology, presentation, interpersonal skills, problem-solving skills, assessment, and writing skills (Robin, 2006). DS is an excellent technological tool for collecting, analyzing, and presenting information. This robust environment offers opportunities to integrate written text with visual images, enabling students to articulate their understanding by merging narratives with visuals and verbal content (Burmark, 2004; Parsazadeh et al., 2021). Moreover, the findings illustrate that DS can enhance students' learning performance and motivation with suitable pedagogical methods (Yang & Wu, 2012). Robin (2008) indicated that DS could improve students' interest in the teaching content, facilitate discussions about the subject taught, and help make the conceptual content more understandable. The

researcher also asserted that the inclusion of rich multimedia elements captured students' attention and motivated them to explore new subjects. This study defined DS as an educational technology created by combining multimedia features, such as images, graphics, pictures, and sound, where users develop the content/story.

DS, as an open-ended learning tool, promotes the acquisition of critical core skills of CT. Stories like codes, constituting the milestones of DS, are told in logical sequences, and repetitions are usually used (e.g., loops). encompasses elements such as characters and locations that are flexible, reusable, or interchangeable, resembling data or variables. Stories in DS are constructed through abstraction, employing a standard story structure, and organized logically using decomposition, akin to scenes. Consequently, DS provides a diverse array of opportunities to impart basic computing concepts, foster creativity, enhance self-expression, and refine children's computing and literacy skills (Dietz et al., 2021; Emara et al., 2021; Isbell, 2002). Kordaki and Kakavas (2017) proposed a framework for each stage of digital story development, highlighting the connection between CT skills and skills cultivated in DS. Drawing from DS studies in the literature (Chung, 2006; Robin & McNeil, 2012; Wang & Zhan, 2010; Werby, 2012), the researchers delineated tasks for each stage in a framework, encompassing setting the scene, designing the story, digital story development, and assessing the digital story. In this proposed framework, DS serves as a pedagogical strategy that introduces novel learning opportunities for learners to enhance their CT skills. Therefore, the DS process holds the potential to augment CT skills.

The framework proposed in this study serves as a pedagogical strategy, introducing innovative learning opportunities for learners to refine and enhance their CT skills, as depicted in Fig. 4. Consequently, the DS process holds the potential to cultivate and develop CT skills. The CT components discussed in this study align with various elements of the DS development process, including:

- *Data Collection and Analysis*: Encompasses the collection of information, making sense of data, identifying patterns, developing insights, and drawing conclusions.
- *Data Representation*: Encompasses identifying general principles and effectively organizing data using charts, graphs, words, or images.
- *Decomposition*: Involves breaking down problems into smaller and more manageable parts for easier problem-solving.
- *Abstraction*: Involves discerning essential information for problem-solving, establishing patterns, drawing generalizations from specific instances, and incorporating parameterization.
- *Generalization*: Entails extending the problem-solving process to a wide variety of problems.
- *Algorithmic Thinking*: Encompasses taking inputs, executing a series of step-by-step instructions, and producing outputs to achieve a desired goal.
- *Testing and Debugging*: Encompasses assessing the efficiency of the resolution process, identifying actions deviating from the intended outcome, and possessing the ability to rectify errors.

These components, discussed in the context of CT, are seamlessly integrated with the DS development process, highlighting the interconnected nature of CT skills and

the DS approach (Barr & Stephenson, 2011; Grover & Pea, 2013; Kilpeläinen, 2010; Selby & Woollard, 2013; Tengler, Kastner-Hauler, Sabitzer, & Lavicza, 2021a, 2021b; Yadav et al., 2014; Wing, 2006, 2008).

This study suggests that DS educational technology can serve a dual purpose as both a learning and teaching tool. It also addresses a question from Wing (2008) regarding incorporating CT into the realm of cognitive abilities, posing inquiries about the optimal timing and approach for individuals to acquire this type of thinking and the suitable timing and methods for teaching it. Thus, PST used DS as an open-ended learning tool for two purposes. First, they have experienced overlapped relationships between CT skills and components of the DS process; second, they designed their stories to support CT components.

### 2.3 Purpose of the study

This study investigates a teacher training program's impact on the PST's CT skills, the CT-integrated DS design skills, and their perspectives. The research also delves into the potential of DS projects created by the PST to bolster CT components, and it explores the perspectives of the PST on the overall process. The study addresses the following questions:

*RQ1:* Is DS effective in promoting the PST's CT skills?
*RQ2:* To what extent do the PST's projects reflect the characteristics of story/storyboard, DS, and CT?
*RQ3:* What are the perspectives of the PST on the implementation process?

## 3 Method

In the study, an embedded mixed-method research design was employed. The embedded design represents a combination of qualitative and quantitative research methodologies, where one data set is supplementary in a study mainly reliant on the other type of data (Creswell & Clark, 2011). Pre and post-test design was used for the quantitative part of the study. The PST's reflection reports and the DS they developed were used in the qualitative part of the study. The research design is depicted in Fig. 1.

### 3.1 Study group

The study was conducted with 52 sophomore PST, 11 male and 41 female students who enrolled in the Instructional Technologies Course from different Faculty of Education programs. These programs are guidance and psychological counseling, primary education, early childhood education, and English language education. The PST were coded as "S1, S2, S3, …".

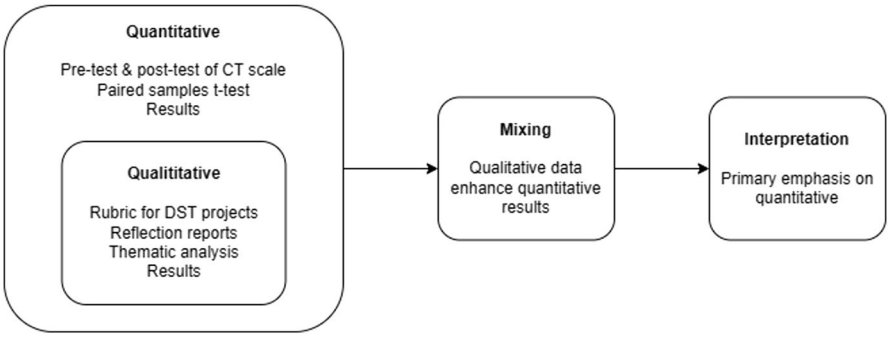


**Fig. 1** The research design (Adapted from Creswell & Clark, 2011)

### 3.2 Data collection

The CT scale was used as a pre and post-test to examine the development of the PST's CT skills, and quantitative data was collected. The qualitative data comprise the CT-integrated DS projects developed by the PST during the training and the reflection reports they wrote at the end.

#### 3.2.1 CT scale

The CT Scale was used to evaluate the PST's CT scores. It was developed by Korkmaz, Çakır, and Özden (2017) to assess the CT skills of undergraduate students. This scale consists of 29 items rated on a five-point Likert (1: Never, 5: Always) scale. The Cronbach's alpha values for internal consistency were reported as 0.82 for the overall scale, 0.84 for creativity, 0.86 for algorithmic thinking, 0.86 for cooperativity, 0.78 for critical thinking, and 0.72 for problem-solving in the original study.

#### 3.2.2 Story/Storyboard, DS, and CT skills rubrics

In the study, the DS projects developed by the PST were assessed using three rubrics developed by the authors: (a) Story/Storyboard (a template/graphic editor used to organize the flow of story scenes), (b) DS (transferring the scenes arranged in the Storyboard and the planned multimedia elements to the digital environment), and (c) CT Skills.

The first purpose of the story/storyboard's rubric was to evaluate whether the language of the story was understandable, whether it had a correct sequence, whether it was impressive, coherent, engaging, and easy to understand, and whether it had a cohesive and strong narrative. The second purpose was to evaluate the story's organization, its elements' arrangement (scene number, title, story text, visual, sound, music, etc.), and the scenes' consistency and, therefore, the story's integrity. This rubric was created based on Sarıca and Usluel's (2016) study: a) Story/Clarity, b) Story/Fluency, c) Storyboard/Organization, d) Storyboard/Organization, and e) Storyboard/Integrity/Fluency.

The scoring level was arranged to be scored between 1 and 3. The minimum score that can be obtained from the rubric is 5, and the maximum score is 15 (see Appendix Table 4). The DS rubric assessed the DS's integrity regarding clarity, originality, practical usage of images, and balance of music and voice. Considering all the components of the DS (story text, sound, music, visuals, etc.), it was evaluated whether each scene complemented the other and formed a whole. This rubric was structured based on Sarıca and Usluel's (2016) study: a) Clarity, b) Originality, c) Image/Video Effectiveness/Relevance, d) Music Voice & Volume, and e) Integrity/Fluency. The scoring level was arranged to be scored between 1 and 3. The minimum score could be obtained from the rubric was 6, and the maximum score was 18 (see Appendix Table 5). The CT skills rubric aims to evaluate the level of CT skills regarding problem statement, data collection and analysis, abstraction, decomposition, generalization, data representation, algorithm design, and testing and debugging. This rubric was developed on Angeli et al.'s study (2016), and the scoring level was arranged to be scored between 1 and 3. The minimum score could be obtained from the rubric was 8, and the maximum score was 24 (see Appendix Table 6).

For the content validity of the rubrics, two experts were asked to review them, and corrections were made following their feedback. To ensure the inter-rater reliability of the rubrics, two experts separately scored 11 final projects in the study group. According to the results of Spearman's rho test, a high correlation was determined between the scores given by two experts for the story/storyboard ($r=0.837$, $p<0.01$), DS ($r=0.92$, $p<0.01$), and CT skills rubric ($r=0.884$, $p<0.01$) (Wood, 2007).

#### 3.2.3 Reflection reports

The PST's perspectives on teaching and learning CT were collected using a form consisting of open-ended questions developed by the authors. The PST were asked to write reports reflecting how they defined CT, the perceived benefits of CT and DS, and their perspectives on how DS promoted CT in the form.

### 3.3 Data analysis

The analysis of quantitative data employed the paired samples t-test. Before the analysis, an examination was conducted to ensure the data met the normality assumptions. Table 1 displays the kurtosis and skewness coefficients for both pre and post-test data, along with the results of the Kolmogorov–Smirnov and Shapiro–Wilk tests. The data indicated a normal distribution. Thus, the paired samples t-test was applied for further analysis.

Two methods were employed to analyze qualitative data: 1) The researchers developed a rubric to assess the CT-integrated DS projects developed by the PST. 2) Reflection reports were analyzed using thematic analysis. Themes or patterns can be analyzed inductively or "from the specific to the general" or theoretically, deductively, or "from the general to the specific" with thematic analysis (Braun & Clarke, 2019). In the current study, qualitative data were examined using the inductive method, which attempted to reach the general from the specific. The analysis

**Table 1** Normality test results for pre-test and post-test

| | Kurtosis | Skewness | Kolmogorov–Smirnov | Shapiro–Wilk |
|---|---|---|---|---|
| Pre-test | 0.083 | -0.643 | 0.084 ($p=0.200$) | 0.983 ($p=0.647$) |
| Post-test | 0.206 | -0.402 | 0.081 ($p=0.200$) | 0.981 ($p=0.584$) |

yielded four thematic frameworks (See Fig. 2). The internal validity of the form created by the researchers regarding reflection reports was ensured by having them examined by two external field experts. Besides, the qualitative data were coded by two authors, and the reliability between them was calculated using the Kappa coefficient. The Kappa coefficient was calculated as 0.86. According to this result, the strength of the agreement between the two encoders is relatively high.

The DS projects were examined using the rubrics explained above in the study and the data were analyzed with descriptive statistics.

### 3.4 Implementation process

An eight-week training session was organized to promote the PST's CT skills (Fig. 3). The PST developed DS in groups of 2–3 people. In this study investigating the impacts of the DS developed by the PST on their CT skills, the PST presented a problem while determining their stories. While writing their stories, they reflected on how they used their CT skills in solving this problem under the guidance of the rubrics given to them. Figure 3 depicts the implementation process.

The pre-test was applied to the PST at the beginning of the training. The theoretical content of both DS and CT was shared with the PST in the first two weeks, and then the participants started to work. While the stages and features of CT and DS were explained, the PST started to work by forming their groups simultaneously.

Firstly, the groups determined the story's goal and stated the problem statement. The groups explored the target audience's characteristics based on the story's

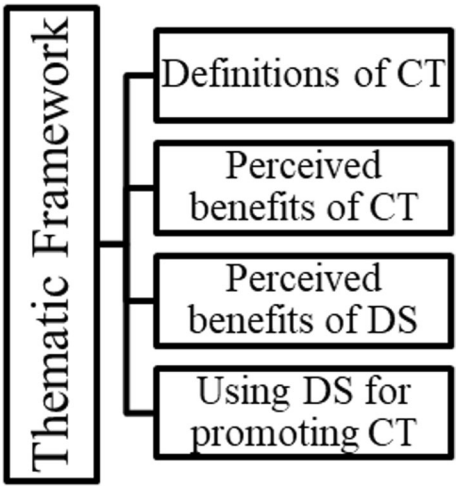


**Fig. 2** Thematic framework

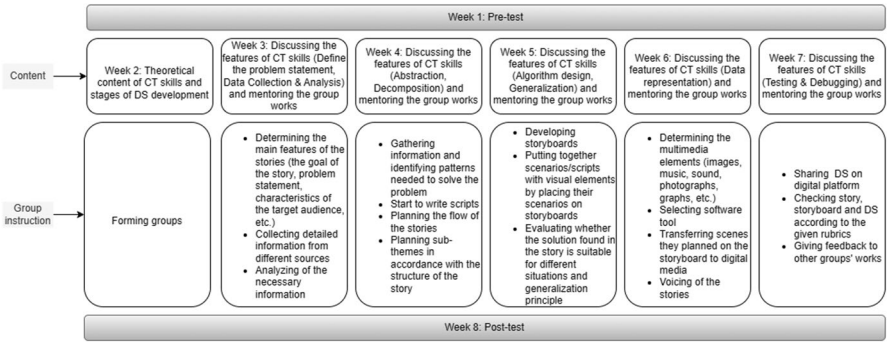


**Fig. 3** The implementation process of the study

objective and the contextual problem. In line with the goal, they determined the subject and the characters of their stories by analyzing the necessary information, such as for whom, on what subject, and at what level the story would be written. Moreover, they brought together the data they collected by researching the internet and/or other sources to acquire more detailed information about the subject (CT Skill: Data collection and analysis). Consequently, they concluded the phase of collecting essential information for problem-solving and identified patterns crucial for addressing the issue (CT skill: Abstraction).

Then, they continued to plan the flow of their stories by discussing which CT skills they would reflect at which stages of the story while creating the pattern of events that the script characters would encounter. While defining these stages, they organized the story flow properly by embodying the information and events that will form the skeleton of their stories. During this process, they decomposed the subject they were working on into sub-themes by the structure of the story. (CT skill: Decomposition). Groups developed the storyboards, which had a consecutive structure in which they organized the flows of digital story scenes, including narratives to be played on each scene by dividing the story into scenes (CT Skill: Algorithm design).

At this stage, the generalization principle was observed after the completion of the story/storyboard process, which the PST created by following a particular order and steps. They evaluated whether the solution they found based on the story's main idea (problem situation) was suitable for adapting to different situations and generalizing. Additionally, the PST evaluated the potential enhancements of their digital story by considering the addition or removal of specific elements (CT skill: Generalization).

Afterward, they selected related data and DS materials (such as location, background images) related to their stories. This structure helped PST to plan the multimedia elements (pictures, music, sound, photographs, graphs, etc.) and in which scene they would need them before transferring their stories to the digital environment (CT skill: Data Representation). Afterward, the PST selected the software tool (e.g., My Storybook, Storybird, StoryJumper, Animoto, iMovie) to digitize their stories.

They then transferred the scenes they planned on the storyboard to digital media using their chosen digital tool. They also enriched their digital stories using other

multimedia tools such as templates, characters, pictures, and music in this software tool. They voiced their stories and shared their completed products on digital platforms.

At the beginning of the process, rubrics outlining the criteria for DS dimensions (story/storyboard, digital form of storytelling, and CT skills) were provided to the PST. Consequently, the PST had a set of instructional rubrics guiding them in developing an effective DS that fosters CT skills throughout the entire process.

Additionally, the PST received feedback from other groups in the class within the framework of this rubrics (CT skill: Testing & debugging). The groups corrected their projects according to the feedback. Afterward, the groups' projects were evaluated by the instructor. The post-test was administered upon completion of the training.

This study designed DS as an open-ended learning environment and used it to promote PST's CT skills and CT teaching skills. So, this study investigates and presents evidence from CT-integrated DS usage in teacher education, except programming tools and educational robotics. Thus, the model developed and used in the study is represented in Fig. 4.

## 4 Findings

### 4.1 The paired samples t-test results

The paired samples t-test was utilized to examine whether a significant difference existed in the PST's computational skills before and after the training. The results of the paired samples t-test are presented in Table 2. The scores obtained by the PST from the post-test are higher than the pre-test scores. Furthermore, a moderate linear correlation was found between the PST's CT pre-test and post-test scores ($r = 0.628$, $p < 0.000$).

Table 2 shows a significant difference between the PST's computational skills ($t = -3.674$, $p = 0.001$) in favor of the PST's post-tests (pre-test = 101.59, post-test = 107.62). In brief, PST's computational skills increased significantly at the end of the training. Cohen's d-effect size was calculated as 0.51 (by dividing the mean difference by the standard deviation of the difference). Accordingly, a medium effect size was obtained in developing the PST's CT skills due to the training.

### 4.2 Assessment of CT-integrated digital storytelling projects

In the study, the DS projects developed by the PST were assessed using the rubric with the dimensions of Story/Storyboard (Appendix Table 4), Digital Storytelling (Appendix Table 5), and CT Skills (Appendix Table 6) prepared by the researchers. Scores that can be obtained from the story/storyboard rubric are (Min: 5; Max: 15); from DS (Min: 6; Max: 18); from CT (Min: 8; Max: 24). Table 3 contains descriptive statistics for the scores the PST obtained according to the Story/Storyboard, Digital Storytelling, and CT Skills dimensions as a result of the evaluation of the 26 projects they developed.

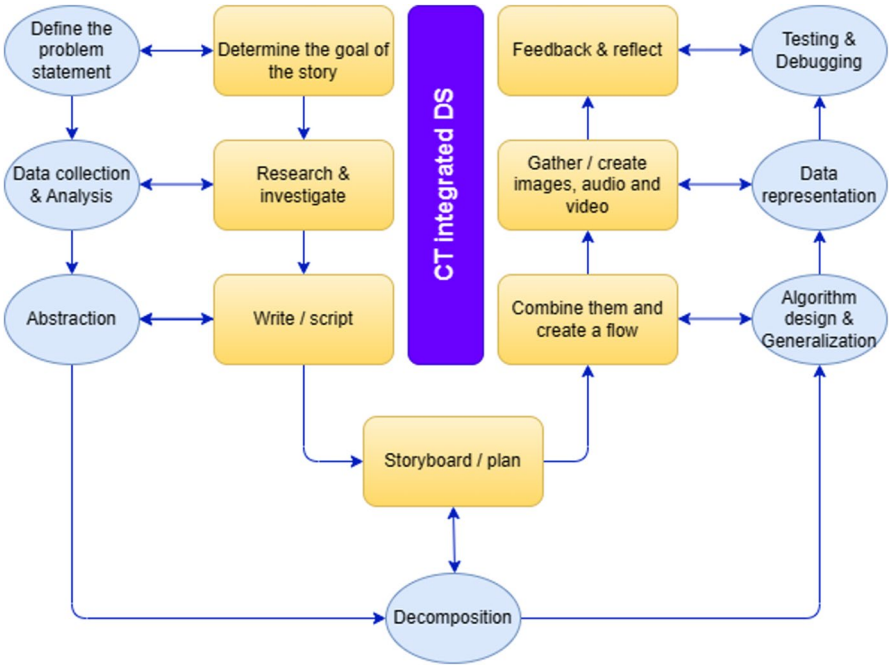


**Fig. 4** CT integrated DS

**Table 2** Paired samples t-test

| | Mean | N | SD | SE Mean | t | df | *p* |
|---|---|---|---|---|---|---|---|
| Pre-test | 101.59 | 52 | 13.66 | 1.89 | | | |
| Post-test | 107.62 | 52 | 13.73 | 1.90 | | | |
| Pre-test & Post-test | -6.02 | 52 | 11.82 | 1.64 | -3.674 | 51 | 0.001 |

The scenes in which the abstraction, algorithm design, and debugging skills are aimed to be supported are given with the pre-service teacher's statement from the storyboard design of a Project, as an example in the DS projects developed by PST.

The example aims to support the CT skills of 2nd-grade primary school students in solving a problem they encountered in the social studies course on way finding. The story's title is "Kevin and Friends' Jungle Adventure" (see Fig. 5).

### 4.3 Qualitative findings

The examination of qualitative data uncovered the presence of four discernible themes: (a) definition of CT, (b) perceived benefits of CT, (c) perceived benefits of DS, and (d) perspectives on using DS for promoting CT.

**Table 3** The evaluation results of the DS projects developed by the PST

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Story/Storyboard | 23 | 12 | 15 | 14.70 | 0.703 |
| DS | 23 | 16 | 18 | 17.78 | 0.518 |
| CT skills | 23 | 16 | 24 | 22.52 | 2.761 |

#### 4.3.1 Definitions of CT

CT definitions made by the PST at the end of the training were analyzed in terms of word frequency. Accordingly, the first ten most commonly used concepts (especially CT) were as follows: *problem-solving, computer, problems, technology, process, human, data, step, and solution.* Upon examining the definitions made by thematic analysis, the content of the PST's definitions was collected at three points: (i) computer and technology use, (ii) problem-solving process, and (iii) data (systematize, organize, or analyze), develop methods, human and technology relationship, and other skills. The examples of the PST's definitions are presented below:

*"CT is the most effective and healthy way to solve problems." S24*
*"CT skills help to solve problems and create a formula with tools such as a computer." S18*
*"Computational skills are analyzing data for problem solutions, determining certain steps, and transferring them to different issues by generalizing problem-solving skills." S12*
*"It uses algorithmic thinking; in other words, it follows several steps by dividing problems into small pieces." S45*
*"In my opinion, the computational skill is the passage between the human mind and the computer mind." S21*

#### 4.3.2 Perceived benefits of CT

Within the benefits perceived by PST, two sub-themes emerged: (a) professional and (b) personal advantages. The PST aim to implement these activities into their future practices because they believe that integrating CT into the teaching and learning process would be beneficial. Considering that most PST receive education in psychological counseling and guidance, it can be argued that they make exciting suggestions regarding their field of practice. Moreover, the PST asserted that CT would make a valuable contribution to students, emphasizing the development of essential skills such as data collection, data analysis, algorithm design, breaking down complex problems into manageable parts, and generalization:

*"Since computational skills also develop the algorithms' logic, they transform the issue from superficial to permanent because students reach the source of the problem step by step while solving it and act by following the steps." S5*



**Slide 1:** Kevin's learning of ways.

**CTS (Computational Thinking Skills):** Abstraction

**Telling of slide 1(scene 1):**
Kevin was on his way to take his mother's basket of food to his grandmother. To cross the street, Kevin looked to the right, then to the left, to check for a car.

It was aimed that Kevin, who is a 2nd-year primary school student, should look to the right, then to the left, and again to the right to cross the road, thus reminding the students of the traffic rules and reinforcing the abstraction skills.



**Slide 2:** Kevin's dialogue with his friends

**CTS (Computational Thinking Skills):** Define the problem statement

**Telling of slide 2 (scene 2):**
While walking down the street, Kevin encounters his classmates Mark and Paul. Mark: Kevin, how are you? Kevin: I'm fine, I'll get grandma food. Paul: Wow, what are you taking to your grandma? Kevin: My mom made muffins and cookies for my grandma, I'm taking them away. Paul: I'm hungry too, can I come with you? Kevin: Of course you can. Mark: We can even play games there.

Kevin and his friends meet and they talk about Kevin's mission.



**Slide7:** Kevin and Paul's struggles to save Mark

**CTS (Computational Thinking Skills):** Algorithm design

**Telling of slide 7 (scene 7):**
Mark, Paul, and Kevin were walking, chatting without looking ahead. They did not see the pit in front of them, and Mark suddenly falls into the pit. Paul and Kevin consider how to save Mark. Kevin sees a tree branch and immediately takes it and gives it to Mark, but the branch breaks because it is thin. Paul comes to mind to use his belt and quickly takes it off and hands it to Mark, making Mark come out of the pit.

A friend of his in the forest falls into a pit and they think to save him. In order to overcome this obstacle, they look for solutions by using the tools around them.



**Slide 12:** Kevin's derive lessons from mistakes from this adventure

**CTS (Computational Thinking Skills):** Debugging

**Telling of slide 12 (scene 12):**
If I had chosen the forest road that I always use for the return and taken my friends from there, we could reach our home more risk-free and easier.

Kevin realized his mistake and said that they should use the return path he always used. Talking among themselves, they decided that it was important for them to take the route they were sure of the next time they came.

**Fig. 5** An example of the projects developed by PST

*"Computational skills teach students to solve problems. To solve problems, they divide problems into small pieces and follow several steps so that students can easily solve problems." S19*
*"....At the same time, we can show it step-by-step in learning and doing something well because the stories we write go on in an algorithmic order. We can see that the computational skills we use in solving these step-by-step problems also help us understand technology integration." S4*

The PST said using CT in their personal lives and for their professional benefits would benefit them. The PST indicated they could solve the problems they might encounter using CT skills in their daily lives more easily. The examples of the relevant statements of the PST are given below:

*"For example, if we can use our algorithmic thinking skills against a problem we encounter in life, the problem we face will no longer be a problem for us; it will be just a normal event." S33*
*"It allows us to arrange the data and present them differently." S40*
*"… with the help of the DS project, I got a chance to improve my CT skills. This project helps me to understand the meaning of skills more clearly." S37*

#### 4.3.3 Perceived benefits of DS

The PST stated that DS could employed across various subjects and educational levels to enhance students' diverse learning skills and abilities. The following statements, including the PST's views, are presented below:

*"We wrote problem-solving-focused stories during the DS project and learned how to use them for our future students." S44*
*"We wrote our story first, we planned it on the storyboard, and then we supported the story using visuals and voicing. By doing this step by step, we have always benefited from the applications that technology offers us, but most importantly, we have improved our problem-solving skills." S46*
*"I thought digital storytelling was the most productive assignment because the stories we wrote were based on solving one or more problems and fixing things." S4*
*"...students should be able to relate the narrated story to the subject of the lesson, to create the cause and effect relationships given in the story on a better basis, to embody and understand abstract concepts, to think critically, and to follow the steps of problem-solving. At the same time, such stories are a way to instill students in social issues." S51*

The views of the PST on the StoryJumper tool used for DS implementation are as follows:

*"StoryJumper teaches to create a story in algorithmic order, which teaches to create a beautiful digital book by following the rules." S23*

*"Owing to these tools, we create informational and educational stories for students and help them to develop their cognitive development." S44*
*"It means StoryJumper is pretty appropriate for primary and elementary school education. There are some skills that students are expected to acquire at the end of the process. They should have had a script that stands on its own merits and has visuals, narration, music, animations, etc., at the end of the process." S34*

#### 4.3.4 Using DS for promoting CT

Considering the PST's perspectives on DS's role in promoting CT, they believed DS could potentially boost students' CT skills. The PST stated their aim to integrate DS to improve their future students' CT skills. They also found the DS implementation beneficial and stated they would allow them to use it in their own and their students' practices in the future. Some statements of PST are given below as examples of these views:

*"Because I am the teacher of the future and through this application (DS), I can teach my students different subjects. I can teach, for example, problem-solving, algorithmic thinking, etc." S9*
*"At the end of this book, we may have had the opportunity to tell a story that affects children and gives them a new perspective and skill." S33*
*"It can be attractive for children of this level to start with storytelling the subject. The subject to be taught is divided into steps according to its achievements." S10*
*"As a future educator, I am sure that through this application, my students will learn and gain experience of the sense of cooperation, problem-solving ability, CT ability, and algorithmic thinking ability, and their imagination will increase at a very positive level, and the integration of education into technology will become even easier." S31*

It is observed that the PST found the DS implementation valuable for promoting CT. Additionally, they also expressed in their statements that they would allow its implementation in their future and in students' practices:

*"Also, it is created for different purposes and lessons. For example, critical thinking topics such as problem-solving, CT, and algorithmic thinking can be learned with steps in digital storytelling. Therefore, students can observe and learn gradually and integrate it into their lives. Many topics like this can be conveyed gradually and effectively. I can say that the content of this tool is broad and varied. All of these features are very beneficial for people." S49*
*"DS helped many children to learn significant mathematical and computational concepts that improved their creative thinking skills, problem-solving, logical reasoning, and collaboration skills." S19*
*"However, now I am trying to find a solution by breaking down the problem. This is the one component of "CT." Also, as a preschool pre-service teacher, it was vital for me to learn how to create a story in the digital environment." S49*

*"When I provide psychological counseling and guidance services, I can teach how to prepare games that support algorithmic thinking for teaching CT; for example, I can teach CT skills by designing a digital story in which a person experiences a communication problem and showing how to solve it with algorithmic thinking." S30*

The PST's views on the process of data collection and analysis while writing their stories are as follows:

*"....In addition, owing to DS, students' algorithmic thinking is supported. Owing to this algorithmic thinking, students try to find solutions to complex problems by following a series of steps. In this way, students' problem-solving and critical-thinking skills develop. Additionally, students try to solve complex problems by dividing them into smaller pieces using CT. In this way, it supports students' CT." S11*
*".....In addition, they enable students to work individually or in groups, so students' imagination, collaboration skills, etc., support their development. Just as students' CT skills improve with StoryJumper (DS), these are decomposition, abstraction, algorithmic thinking, generalization, and debugging." S11*
*"DS can be easily used in any student's educational process at the K-12 level. Students acquire many experiences through the process in which they use StoryJumper. For example, cooperation, problem-solving, CT, and algorithmic thinking abilities. To integrate this kind of practice into the learning-teaching environment in the classroom, we can group students in the classroom and summarize the application to them." S18*

## 5 Discussion

The present study used mixed methods to examine the outcomes of a teacher training program designed to promote the PST's CT skills and CT teaching skills. The study uses DS as an open-ended learning environment to enhance the PST's CT skills. To assess the impact of the implementation process on the development of CT skills, an analysis was conducted, considering pre-tests, post-tests, rubrics, and the perspectives of the PST. As a result of the training program designed and followed in the study, the PST's CT skills increased significantly in favor of the post-test. The story/storyboard, DS, and CT components of the DS projects developed by the PST were evaluated through rubrics. The digital stories adequately reflected the CT components. Moreover, the qualitative findings supported the quantitative findings. The PST's expressions to define CT are consistent with CT definitions in the relevant literature. Most PST stated that learning and teaching CT was beneficial for them in their professional and personal lives. Furthermore, they have professional plans to use DS in their teaching in the future. The PST also emphasized the role of DS in the development of CT skills. Furthermore, the DS projects were sufficient regarding the features the story and storyboards should have. In this respect, it also supports the pre and post-test findings.

Unlike previous studies, this study followed a process in which PST made an effort to be aware of the CT components and integrate them into the DS process at the higher education level. Previously, Yildiz Durak (2018) found that using DS

in the programming education of fifth-grade students significantly increased their learning self-efficacy concerning programming and participation in the learning process. Additionally, some experimental studies emphasize the critical role of DS in enhancing CT skills. Tengler et al., (2021a, b) demonstrated that engaging in robot-based storytelling activities led to an enhancement in the CT skills of students in the third and fourth grades. Yang et al. (2023) reported that story-inspired programming education contributed positively to the CT development of preschool students. Hence, the results derived from this study make a meaningful contribution to the field, as they align with existing literature.

The PST's perspectives on the implementation process were analyzed. Qualitative findings reveal PST's perspectives on CT definitions, perceived benefits, and CT-integrated DS preparation processes. While defining CT, the PST focus more on problem-solving, technology use, process, and data solution. In their experimental studies on CT, Taslibeyaz et al. (2020) reported problem-solving, programming, human behavior, and system design expressions at a higher frequency in CT definitions. Accordingly, the PST's definitions of CT overlap with the critical statements in the definitions in the literature. The PST mentioned the key concepts used in the definition of CT. In line with previous studies (e.g., Tankiz & Atman-Uslu, 2023), the PST indicated that learning and teaching CT benefited them professionally and personally.

According to the results of a systematic review study, Dong, Li, Sun, and Liu (2024) reported that there were various methods, such as courses, programming environments, educational robotic interventions, modules, projects, and seminars, to develop CT. Previous studies on teacher education show that CT projects and modules are focused on less (Dong et al., 2024). The present study aimed to enhance the CT skills and CT teaching skills of PST by emphasizing a project development task related to CT within the framework of the Instructional Technologies Course. Consequently, this study showcased the CT skills development of the PST in a project task, utilizing DS instead of conventional programming tools or educational robotics. Furthermore, it revealed that the steps followed in the implementation process were promising in associating, overlapping, and integrating CT components with DS steps.

To conclude, in light of findings from different data sources and various assessment approaches, the implementation process supports PST in terms of integrating CT components into DS. Therefore, the current study presents early findings showing that CT components could be integrated with DS and used in teacher education effectively without any pressure to use programming tools.

## 6 Implications, limitations, and future studies

This study includes an educational intervention in which DS is used as an open-ended learning environment to develop PST's CT skills. The findings of the study reveal that the CT integrated DS process promotes the CT skills of PST, and contributes to their CT-integrated DS design skills, their understanding of the CT concept, and their perception of benefit. The research findings emphasize the value of DS for using CT in

learning and teaching processes. Based on these points, it is recommended that educators and researchers in teacher education can use DS to strengthen CT skills. This study's findings may also shed light on how in future the stages of CT and DS could be integrated. Hence, the steps followed in this research process can be employed by instructors working in teacher education. Thus, this study considered every CT component when developing DS projects. Accordingly, the present study took a step to contribute to the literature by examining CT components in more detail.

The current study confirms the previous research results which indicate that DS can be used in CT development. Additionally, unlike the previous research, it brings about pioneering findings that show how DS can be used for the CT learning and teaching skills of PST for K-12 students. Moreover, it shows that DS, instead of programming environments, supports the CT skills' development. Neverthless, it is necessary to report the limitations of the study. The quantitative part of the study employs a single-group pre-test-post-test experimental approach. Research investigating the use of different tools in developing PST's CT teaching competencies will also be effective for future teaching practices. Therefore, comparing the DS usage with different pedagogical tools and environments in future research is recommended. Further studies can focus on the role of DS on PST's ability to teach CT. Moreover, the study covers eight weeks. Although this process leads to improvements at the desired levels in PST, future research can investigate the impacts of more intense and long-term education on PST.

Finally, this study has its limitations: first, the risks of including only one experimental group in our research and how we addressed them. We used an embedded mixed-method design to understand whether the effects observed in this study were due to the intervention or other external factors. This design allowed the data to be triangulated and the development of PST's CT and future CT teaching skills from multiple perspectives was examined. In addition to self-report measurement, the study evaluated the DS projects developed by PST in terms of Story/Storyboard, DS and CT components, and reflection reports were used to examine how PST perceived CT and promoting CT using DS in the context of the intervention. Furthermore, the intervention was discussed in full detail and conveyed to the reader to ensure the that results could be generalized to the single group and the lack of diversity or variation in the experimental conditions. By considering these multiple factors, the study's validity and reliability were strengthened. In order to analyse the vitality and generality of the study's findings, in the future researchers will aim to replicate it using further samples or alternative scenarios.

Within those learning environments in which DS was open-ended way to encourage CT skills, students found that they could articulate themselves and enhance their problem-solving skills. Additionally, the skills acquired through CT can be used in various contexts where students must generate content. In this training, PST create a DS environment where their learning is made more permanent by strengthening their own CT skills, and they have the opportunity to support their students' CT skills in the future. Thus, they experienced these learning environments in which "learning by doing" was encouraged in line with their self-learning goals. Consequently, in this training, DS served as both a teaching and learning tool for PST in creating an open-ended learning environment.

# Appendix

**Table 4** Rubric for story-storyboard

| Categories | Proficient<br>3 | Developing<br>2 | Minimal<br>1 |
|---|---|---|---|
| Story/Clarity | The story employs well-chosen words, ensuring clarity and understanding. There are no words that might be unfamiliar, making it easy for the reader to comprehend the intended narrative | The story's words are not chosen carefully, and words with unknown meanings are used in some places. Despite this, what is meant to be told in the story is clear | The story's words are not well chosen. Unknown words are used. The story is quite challenging to understand |
| Story/Fluency | The story is written in the correct order, impressive, coherent, gripping, and easily understandable in a harmonious and robust manner. Harmony is supported in the transitions between the expressions in the story | Although the story was written partially in the correct order and consistently in harmony, more robust and more varied expressions could have been used, and it could have been written more grippingly | The story is not written in the correct order, coherent, gripping, and understandable. It is seen that harmony is not supported in the transitions between the narrations in the story |
| Storyboard/ Organization (selection of pictures, paragraph structure) | Images about the script are well chosen, paragraphs used in the narration are at the appropriate length for the student's level, and the number of lines is not too much | Images about the script are not carefully selected, and the lengths of the paragraphs and the number of lines used in the narration were not adjusted according to the level of the student in some scenes | Images about the script are not well chosen. In some places, it is seen that paragraphs used in the narration are not the appropriate length for the student's level, and the number of lines is too much |
| Storyboard/ Organization (the elements of the storyboard) | In the scripting of the story, the components (scene number, title, story text, visual, and information about sound, music, etc.) that need to be found in the story are arranged in a way that supports each other appropriately | While the elements (scene number, title, story text, visual, and information about sound, music, etc.) that should be on the storyboard in the scripting of the story are arranged in a way that supports each other in accordance with the purpose of the arrangement is ignored in some sections | The elements (scene number, title, story text, visual, and information about sound, music, etc.) that must be found in the story are not arranged to support each other appropriately |
| Storyboard/Integrity/ Fluency | All the contents (story text, visuals, etc.) used in the storyboard are consistent and complementary in each scene. The transitions between the scenes on the storyboard are in the correct order and gripping | Some of the contents (story text, visuals, etc.) used in the storyboard are consistent and complementary in each scene. The transitions between the scenes on the storyboard are in the correct order and gripping | No content (story text, visuals, etc.) used in the storyboard is compatible, consistent, and complementary for each scene. In the storyboard, the transitions between scenes are not in the correct order and are not gripping |

**Table 5** Rubric for digital storytelling

| Categories | Proficient<br>3 | Developing<br>2 | Minimal<br>1 |
|---|---|---|---|
| Clarity | The contents used in DS (story, visual, audio, music, etc.) are well selected, and no content that is difficult to understand is used. The audience can easily understand DS | The contents (story, visual, sound, music, etc.) used in DS are not considered, and some contents are not understood. The audience seems to have a hard time understanding DS | The contents (story, visual, sound, music, etc.) used in DS are not considered, and some contents are not understood. It is seen that the audience has difficulty understanding the DS |
| Originality | The DS is different from the existing digital storytelling. It is unconventional, it is different, it is creative, it is new, and it contributes to the field in the context of the developed subject | DS is primarily different from existing digital storytelling with the content used, it is unusual, diverse, creative, new, and partially contributes to the field in the context of the developed subject | The DS is similar to the existing digital storytelling with the content used, is not handled in a different way, is not creative, and does not contribute to the field in the context of the developed subject |
| Image/Video Effectiveness/Relevancy | In DS, visuals and/or scenes are high quality, interesting, unique, and touching, leaving a positive impression and creating a different atmosphere | DS's visuals and/or scenes are mostly high-quality, engaging, original, and emotional, leaving a positive impression and creating a different atmosphere | DS's visuals and/or scenes are of low quality and do not leave a positive impression on the audience |
| Music-Voice Volume | Music does not shadow the volume of the speaker. Although the voice of the speaker at a higher height is more dominant, the music in the background is audible. The height of music and sound in DS does not bother the audience | In some places, the music overshadows the speaker's voice. Although the speaker's voice is more dominant with its loudness, the background music can be heard. In DS, the loudness of the music does not disturb the listener | In DS, the volume of the music is more dominant, or in DS, the volume of the speaker is so prevalent that background music cannot be heard. The music and volume level in DS disturb the audience |
| Vocalization | All of the group members made a voiceover | Some of the group members made a voiceover | Not all members voiced |
| Integrity/Fluency | All contents (story text, sound, music, visuals, etc.) to be used in DS are complementary to each other in each scene. The transitions between the scenes are in the correct order and gripping | The contents in some parts of the DS (story text, audio, music, visuals, etc.) are inconsistent and, in some parts, not complimentary | All content (story text, sound, music, visuals, etc.) used in DS do not complement each other in every scene |

**Table 6** Rubric for computational thinking skills

| Categories | Proficient<br>3 | Developing<br>2 | Minimal<br>1 |
|---|---|---|---|
| **Defining the problem statement**<br>The skill to define a real-life problem | There is a well-structured real-life problem that provides a comprehensive understanding | There is a problem connecting to real life, but it doesn't provide a comprehensive understanding | There is no proper idea related to real-life problems |
| **Data collection & analysis**<br>The ability to collect data, analyze it to identify patterns or gain insights, and draw conclusions | The collected data and structured data analyses are sufficient for the problem situation | More data on the problem situation should have been presented. Data analysis is sufficient for the data presented | No data has been found or analyzed in connection to the problem statement |
| **Abstraction**<br>The ability to identify the necessary information for problem-solving, identify patterns and generalize from specific examples, and utilize parameterization techniques | External reference systems provide a structured framework or representation that effectively addresses and resolves problems | External reference systems are understandably used to build/represent a model and solve a problem | The representation created by external reference systems is not used effectively to solve the problem |
| **Decomposition**<br>The ability to decompose a complex problem into more manageable components that are simpler to comprehend and resolve | Divide a complex activity into a number of manageable, simpler subtasks with clear instructions | Divides a complex work into a number of more manageable, ill-defined subtasks | Divides a complex task into a succession of inefficient subtasks and inadequately described |
| **Generalization**<br>Ability to generalize and transfer features of the problem-solving process to a wide range of problems | The process of applying and generalizing the problem-solving process to different situations is outlined effectively | The steps that work well for generalizing and applying the problem-solving method to many contexts are outlined | The process of applying and generalizing the problem-solving approach to various situations is not outlined in detail |
| **Data Representation**<br>The skill of depicting and organizing data in appropriate graphs, charts, words, or images | The data is organized by adequately describing it with words, images, or pictures | Data is organized pretty much by describing it with words, images, or pictures | The data is not organized by adequately describing it with words, images, or pictures |

**Table 6** (continued)

| Categories | Proficient<br>3 | Developing<br>2 | Minimal<br>1 |
|---|---|---|---|
| **Algorithm design**<br>Define a series of ordered steps to solve a problem or achieve a goal | Define a logical (e.g., clear, precise), efficient series of steps for a solution, and put instructions in the correct sequence | Define a logical series of steps, but the steps are inefficient (e.g., overlapping, unnecessary) | Defining steps have not been defined for a solution or achieved a goal |
| **Testing and debugging**<br>The skill to evaluate the effectiveness of the resolution process and how it can be developed better identify, remove, and fix errors | Recognizing that actions do not follow instructions, removing and correcting errors | Partial recognition that actions do not follow instructions, failure to correct all errors | Unable to recognize that actions do not follow instructions |

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## Declarations

**Competing interests** The authors declare that they have no competing interests.

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