# A Systematic Review of Digital Storytelling in Promoting Thinking Skills in Science Classrooms from 2004 to 2022

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**Abstract.** This study aims to identify activities in digital storytelling that promote three types of thinking skills: associative, visual, and divergent, in science classrooms. To achieve this research purpose, a systematic review of the literature was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The final reviewing process has led to a total of 41 selected articles that were retrieved from six electronic databases: Web of Science, Scopus, ScienceDirect, EBSCOhost, Semantic Scholar, and Google Scholar. These articles were published from 2004 until 2022. Through qualitative data analysis, the results revealed 36 digital storytelling activities that can be implemented in science classrooms to promote students' thinking skills. It can also be concluded from the findings that, for optimal results, the implementation of digital storytelling should incorporate a combination of activities and adopt a collaborative approach to support all three types of thinking skills. Overall, this study highlights the activities of digital storytelling that can develop students' thinking skills and enhance their science learning understanding.

**Keywords:** digital storytelling, thinking skills, science classrooms, literature review.

## 1 Introduction

This study highlights activities in digital storytelling that train students' thinking skills to help them understand science concepts. First, the term "digital storytelling" refers to the ability to tell stories digitally using multimedia elements such as text, graphics, voiceover, a background soundtrack, animation, and video [1][5]. Like traditional storytelling, digital storytelling will focus on a specific topic and include a viewpoint. Nevertheless, the term "digital storytelling" is distinguishable by the process of mixing digital media materials using video editing software to aid audience comprehension of a story in video format. The research studies' findings indicate that using digital stories helps students develop their ability to absorb concepts more deeply and achieve high academic achievement [6-8].

Almost all digital stories are short and concise, typically lasting between 3 and 5 minutes and not exceeding 10 minutes in duration [9]. Generally, the digital storytelling video can be displayed on any electronic device that supports this format and shared online. Although there are various types of digital stories, some academics have proposed categorising them into a few

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narrow groups, such as biographies, history documentaries, and topical stories that educate about a specific topic [10]. Since digital storytelling can assist students in achieving academic success, it has increasingly drawn attention among teachers and students to creating digital storytelling on a broad range of subjects, including science [12–15].

However, science concepts are abstract in nature, and implementing digital storytelling in the science classroom requires activities that can support thinking skills [19–21]. Among the thinking skills that can help students attain a good understanding of science concepts are associative thinking [20], visual thinking [24], and divergent thinking [18].

According to [25], the three thinking skills aforementioned should be mastered in hierarchical order. The first skill is associative thinking, which means making a connection between content knowledge and daily life experience [26]. According to the associative theory, which was put forth by Mednick in 1962, associative thinking aids students in identifying the root causes of their problems and increases the probability that a solution will be found [19]. Hence, the process of linking the prior knowledge to the assigned task requires the student to explore more about the science content, which leads to better comprehension.

The second skill is visual thinking, which is defined as the capability to visually imagine specific concepts [30]. The capability to integrate various meanings of images into a full, visible picture is the primary function of visual thinking. Students can also use visual thinking to make sense of the results of abstract verbal thinking. This is because visual thinking makes an abstract idea more concrete. Its application in studying and analysing research work helps students understand scientific concepts [30–32].

The third skill, called "divergent thinking," is the ability to come up with different ideas that are valued based on what students already know [35]. Hargreaves first proposed divergent thinking in 1927, and Guilford distinguished it from convergent thinking in 1950 [32]. According to a study conducted by [15], students who perform well in science academic tests are also those who are more divergent. Therefore, divergent thinking is an important skill in learning and has a significant relationship with academic achievement.

In contrast, the weakness in these three skills causes students to have problems with science learning. For instance, weaknesses in associative thinking skills contribute to the problem of students' difficulties in making mental images to understand the topic in chemistry [34]. In the topic of acids and bases, the weakness of students' visual thinking skills is in making visual representations related to concepts beyond the scope of the naked eye, which causes students to have misconceptions.

In the different science disciplines, [35] discovered that a lack of visual thinking skills is one of the major contributing factors in making learning physics difficult. He goes on to explain that physics theories like general relativity and the concept of radiation are exceedingly difficult for students to grasp because they deal with generally abstract concepts. Designing and implementing educational activities that aid students in developing visual representations that express their conceptual ideas is crucial. The inability to visualise is significant because it interferes with their ability to make connections, which is dependent on their individual associative thinking skills [36].

As a result, a student's lack of visual and associative thinking skills makes it hard for them to come up with ideas for their assigned tasks. As shown in a survey done by [37], students' test answers were incorrect and only contained one type of answer or idea. The inability to generate ideas is due to the weakness of students' divergent thinking skills [39–41]. Hence, due to the dependency relationship between these three thinking skills, it is essential to carry out teaching activities that can train this set of skills in the classroom to help students better understand science learning [42].

A recent systematic literature review by [42] indicates that digital storytelling can effectively train and incorporate these three skills in a science classroom. The review analysed 40 empirical studies that employed various teaching approaches in science lessons, such as project-based learning, problem-based learning, inquiry, multidisciplinary integration, and hands-on activities. However, there is a gap in knowledge on how digital storytelling processes and activities can specifically promote these essential thinking skills and how they can be incorporated into teaching. Even though there are various versions of digital storytelling activities, they are found to be implemented in standard stages, as illustrated by [43] see **Figure 1.**


**Fig. 1.** Three standard stages in producing digital storytelling.

Nevertheless, the existing digital storytelling process, as described by several digital storytelling scholars, does not pinpoint the exact thinking skill involved in each activity [2][4][5][45–47]. Thus, the activities in digital storytelling that influence thinking skills are still unknown. Therefore, this study fills this gap, guided by the main research question as follows: Which digital storytelling activities promote associative thinking, visual thinking, and divergent thinking?

## 2 Methods

In this study, the systematic literature review (SLR) is used as a way to search articles in a large database of publications on a certain topic and time period in a systematic way. The Preferred Reporting Items of Meta-Analysis (PRISMA) guidelines were used as a guide during the review process. Six electronic databases were searched: ScienceDirect, Scopus, Web of Science, EBSCOhost, Google Scholar, and Semantic Scholar. The articles were retrieved between 2004 and 2022, when they were published. The 18-year time frame was set up due to the first digital storytelling article published in 2004 and continues until 2022 to ensure a comprehensive review process. The review procedure involves four stages (see **Figure 2**).

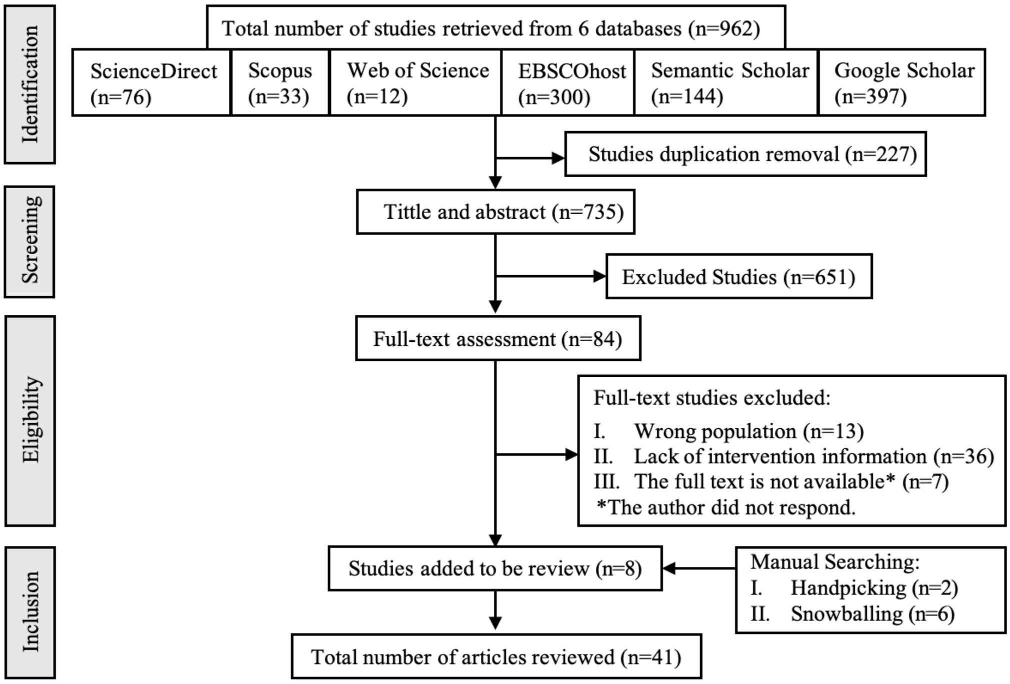


**Fig. 2.** A systematic review procedure based on PRISMA

In the first stage, identification starts with obtaining the primary keyword from the research question, namely, "digital storytelling", "thinking skills" and "science classroom". The identification of related keywords, synonyms, and variations was carried out to further broaden the search. These keywords were later combined in an advanced search by using the Boolean operators OR, AND, or both. The second stage of the screening procedure continued with the criteria for inclusion. For an article to be included in this study, it must be a journal article or a thesis, written in English or Malay, and discuss the effect of digital storytelling activities. As a result, 962 articles have been retrieved from the screening procedure.

### 2.1 Sample

In the third stage, the 962 articles are checked to see if they are eligible by looking at their titles and abstracts. This led to the selection of 84 articles. The selection process is based on the sample involved, which ranges from preschool to tertiary students and is associated with four science disciplines (earth science, biology, chemistry, and physics). In stage four, 84 articles were evaluated for quality, and the Critical Appraisal Tool (CAT) checklist was used to evaluate each of the retrieved articles. The CAT was developed by the Joanna Briggs Institute (JBI) and consists of eleven questions. Each question requires a "yes," "no," or "unclear" response. Not applicable ("NA") is also an option, and in some instances, it may be appropriate. Score 1 if the answer to a particular question in the checklist is "yes", and 0 if it is "no". If the sum of all scores for an evaluated article is equal to or greater than 6 (>50%), then the article is included to be reviewed in this study [47]. As a result, 41 articles with moderate- and high-quality appraisals are included in this study.

### 2.2 Data Analysis

In the data analysis procedure, the main focus has been on getting information about activities that were done to train three types of thinking: associative, visual, and divergent. According to [48], this can be done using a qualitative data analytic process known as the coding method. Through this method, a coding scheme has been developed specifically for the review that highlights the key characteristics of thinking skills. In this study, the coding scheme is established by a 3-step process referring to the coding manual outline provided by [48]. First, identify key concepts and terms related to associative, visual, and divergent thinking. The online thesaurus was used to expand the list of key concepts and identify related terms that are relevant to this study. Second, develop a preliminary coding scheme by organising these concepts into categories or themes. The established coding scheme was later refined and revised in step 3. This is based on new insights and patterns that emerge from the data. This may involve adding new codes, combining or splitting existing codes, or reorganising the categories.

In this study, the three themes of a coding scheme have been established as follows: The first theme, associative thinking, refers to any of the terms used in discussions and conclusions about the influence of digital storytelling activities on science learning outcomes, such as "connecting", "linking", "associating", "combining", "integrating", "bringing together", "correlating", "relationships", "matching", and "putting together". The second theme, visual thinking is any term that is used to talk about academic achievement, such as "visualise", "envision", "picture", "conceptualise", "imagine", "imagination", and "fantasise". The third theme and the last, divergent thinking, refers to any of the following keywords used in discussion related to academic achievement, such as "generate", "produce", "create", "describe", "express", "deliver", "make", "suggest', "process", "put", "construct", "explain" and "initiate".

Finally, a synthesis of the extracted data can be conducted, in which the key findings related to the activities in digital storytelling that promote the development of the targeted thinking skill are summarised and analysed. The extracted data from the included studies was organised using the three stages of the digital storytelling process. Table 1 summarises the overall analysis of each study reviewed. This table contains data extracted from the 41 articles that were reviewed.

## 3 Results and Discussion

The reviewed result in Table 1 will be discussed in terms of the three stages in creating digital storytelling, namely, 1) pre-production, 2) production, and 3) post-production, as illustrated by [43].

**Table 1.** Digital storytelling activities that promote students‘ thinking skills

| Stages | References | Activities | Thinking skills | | |
|---|---|---|---|---|---|
| | | | Associative | Visual | Divergent |
| Pre | [49] | Project-based | / | | |
| | [50] | Hands-on | | / | |
| | [51] | Completing Instructional material | | | / |
| | [5] | Challenging assignment | | | / |
| | [52],[53] | Creating a story based on an experiment | / | | / |
| | [54] | Historical story content | | / | |

| | | | | | |
|---|---|---|---|---|---|
| | [55] | Digital story poetry | | | / |
| | [56] | Group story creation | / | | |
| | [57] | Creating a story plot & sequencing | / | | |
| | [36],[58] | Collaborative project | | / | / |
| | [59] | Writing a story | | / | |
| | [60] | Writing a scenario | / | | |
| | [61],[62] | Script writing | | | / |
| | [8] | Using storyboard & brainstorming sheet | / | | |
| | [63] | Plotting stories in a graphic storyboard | / | | |
| | [64] | Using the phrase relationship | / | | |
| Production | [65] | Drawing | | | / |
| | [66] | Using technology in writing | / | | |
| | [67] | Using a web-based platform | | | / |
| | [68] | Taking pictures with cameras | | | / |
| | [69] | Collaborative video | | / | |
| | [70] | Making of a video | / | | |
| | [71] | Creating the video essay | / | | |
| | [72], [73] | Multimedia integration | | | / |
| | [74] | Creating educational content videos | / | | |
| | [75] | Using video editing software | / | | |
| | [76] | Editing digital story videos | | / | |
| | [77] | Added visual-based technologies | | | / |
| | [35] | Embedding stories with animation | | / | |
| | [78] | Build stories using tools | | / | |
| | [12] | Using a story map | | | / |
| | [79] | Telling a story verbally | | / | |
| | [80] | Voiceover audio recording | | / | |
| Post | [81],[82] | Watching digital storytelling videos | / | | |
| | [83] | Presentations | | | / |
| | [84] | Questioning | | | / |

### 3.1 Digital storytelling activities that promote associative thinking

Based on Table 1, project-based digital storytelling activities train associative thinking at each stage of the digital story creation process [85]. During pre-production, associative thinking is required to create a scenario-based story plot by writing it on a graphic storyboard or using a brainstorming sheet [9][59][65][88]. During story plot writing, students must relate the science topics they learn to real life in story format [64]. The story plot combination in the form of a video essay creates a meaningful relationship between abstract science concepts and daily life phenomena [71]. The involvement of associative thinking in this process is through the ability to conceptually link two story plots based on students' comprehension. Before students can tell the whole story and make their points, they have to do this first [63]. Nevertheless, [87] states that the main challenge for associative thinking skills is finding ideas that need to be connected. Hence, [88] suggests that, to cultivate students' ability to connect different ideas, adopting collaborative activities can help diversify students' ideas.

Under other conditions, making a video using editing software during the production stages assists students in creating digital stories [72][77]. This educational video editing software acts as a platform to help students explore and deliver information about science concepts by incorporating multimedia [74]. According to [66], incorporating multimedia into the writing of a story also helps students include tangible details that prevent them from receiving the wrong idea about science concepts. Unfortunately, because not all students take basic computer courses, their skills in using multimedia presentation software vary [89]. Thus, it's important to make sure that students know how to use computers well enough to add multimedia to their digital stories. Regarding digital story content, [52] suggests creating stories based on lab experiments to give students a chance to think about how their previous experiments relate to what they are learning in class. In addition, [56] suggested that the story creation process be done in groups to provide variation in the respondents' opinions in order to make digital story content more effective. However, this method required more time and teacher support, as well as careful planning [92][93].

In the post-production of digital storytelling activities, associative thinking can be trained during collaborative formative and summative assessments. These assessments can be done in small groups to evaluate the quality of the displayed digital storytelling video produced at the end of the project [83][84]. The reflective assessment can help students learn deeper and for longer when they can identify connections between their experiences [92]. In short, the associative thinking activities involved in digital story creation offer a significant advantage in enabling students to establish connections between their knowledge and real-life content. Nonetheless, for the best outcomes, it is essential to adopt a collaborative approach, manage time effectively, and receive strong support from teachers.

### 3.2 Digital storytelling activities that promote visual thinking

As shown in Table 1, the reviewed result shows how visual thinking is involved in hands-on digital storytelling activities at every stage of making a digital story [50]. During pre-production, writing a story requires students to use their imaginations to create stories that reflect their understanding of science content [59]. For example, a task that challenges students' imagination in seeking an appropriate scientific solution for an astronaut living on Mars [93]. This writing activity allows students to use science facts in a creative way to solve a task that requires imagination. Nevertheless, this activity seems difficult for some students if it is solely dependent on metaphorical thinking. Instead, according to [93] and [69], using a combination of visuals such as a photo of Mars, a spacecraft, a space station, or video simulations helps students' imaginations and makes this activity possible to carry out. At the production stage, the process of adding visual technologies such as embedding stories with authoring tools (augmented reality AR or virtual reality VR), animation, or voiceover audio recording helps students visualise content related to written storyboards [36][79][80][82]. In terms of the story content, the historical story of the real-life scientist develops students' imaginations, and the information becomes more permanent. The historical content in the form of video allows students to picture the events of the story in their minds [94]. Moreover, telling a story verbally and effortlessly helps the student's visual style absorb new ideas into the audience's preexisting schema [79].

At the post-production stage of the digital story activity, collaborative group work helps students successfully complete their projects. According to [36], collaborative digital storytelling activities support students' ability to visualise content in a constructivist environment, which is reflected in enhanced student science academic achievement. Overall, the reviewed studies indicate that hands-on, collaborative digital storytelling activities involving visual thinking occur at every stage of making a digital story. Nevertheless, it is important to note that some students find it challenging to write a story using science facts in a creative way. However, using visual technologies such as science's historical stories presented in the form of videos or told verbally can help students visualise content.

### 3.3 Digital storytelling activities that promote divergent thinking

The analysis based on Table 1 indicates that activities in digital storytelling are capable of integrating divergent skills in the science classroom. At the pre-production stage, the assignment of challenging tasks such as writing a scientific story based on an experiment or using poetry offers students opportunities to comment on scientific phenomena and create quality answers to the task [6][55][6][55][57]. This challenging task can also be used in collaborative work to aid in problem-solving and knowledge construction with classmates [60][97]. However, [51] advises that in order to effectively guide students in collaborative digital storytelling learning, procedures and checklists can be used in this approach to assist students' activities.

At the production stage, divergent thinking can be nurtured through script writing [13], [61] and multimedia integration [72]. During these activities, students are expected to think of new ideas and create a multimedia story. The ability to generate ideas is demanded during these stages to provide unique ideas. The use of a story map is helpful in assisting students to further elaborate on their ideas [12]. Apart from that, the use of alternative media such as web-based platforms or drawings is beneficial to support students in expressing their story ideas [67][69][75]. Meanwhile, [62] stated that taking pictures with a digital camera allows students to examine how content can be changed for illustrations and compare how personal videos express themselves. Yet, students' storytelling skills are different even if they are in the same class. This limitation can be overcome by conducting pre-storytelling training prior to the production of actual digital storytelling [96].

In the post-production of digital storytelling, the infusion of divergent thinking can be identified during the questioning activities of the digital storytelling presentation [85][86]. When students finish a digital story, teachers can implement questioning activities by asking them to think about it and share their thoughts and ideas. Therefore, these activities support students' divergent thinking to be able to generate more ideas that are unique and detailed. As a result, students gain a better understanding of a scientific concept.

## 4 Conclusion

As part of our systematic review, we identified 36 digital story activities that can be implemented in science classrooms to promote students‘ thinking skills (see Table 1). These activities involve students' thinking skills in all three stages of producing digital stories. But then, no single activity in the production of digital storytelling is simultaneously able to train associative, visual, and divergent thinking skills. Hence, the implementation of digital storytelling should combine several activities and integrate a collaborative approach to be able to support all three types of thinking skills. In conclusion, this systematic review contributes to the addition of information about digital storytelling activities that can be used by educators to promote associative, visual, and divergent thinking skills.

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