Digital stories in science

The role of story sequencing

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3.1 Introduction

Stories, along with drawings and narratives, have been found to have a mediatory role in the construction of meaning (Bruner, 1990; Pantidos, 2017). They are a natural form of expression for people of any age and culture (Bruner, 1990). The technique of stories can be used in the organisation of events, facts, characters, and ideas into meaningful units (Hadzigeorgiou, 2016). A story takes its audience through a set of events, all the way from problem to solution and critical engagement with the solution (Polkinghorne, 1996), provoking active thinking and supporting meaning construction (Dettori & Paiva, 2009).

Stories are frequently used in educational settings to support teaching and learning (McEwan & Egan, 1995). As a teaching approach, using stories can stimulate students' critical thinking skills (McDrury & Alterio, 2003) and help them to develop a variety of skills in communication, search, collaboration, and task completion (Di Blas, Garzotto, Paolini, & Sabiescu, 2009). Educators "act as students' role models, agents of socialisation and brokers of knowledge" (Kucirkova, 2018, p. 109), seeking to create and use suitable stories to convey content knowledge and to motivate students to learn (Jackson, 1995). Some educators may decide to create their own stories and then present them to students as a way of introducing new material (Robin, 2006). Others can have their students create their own stories (Robin, 2006). Furthermore, some may choose to co-create a story with their students, as an enjoyable process of negotiating a shared perspective (Kucirkova, 2018). In contrast, as a learning approach the attention is on "finding meaningful ways for the students to make use stories related to their learning tasks, with the aim of facilitating and improving learning" (Dettori & Paiva, 2009, p. 56).

A substantial number of changes in the presentation and delivery of stories is made possible by emerging technologies (Chen, Ferdig, & Wood, 2003). The advancement of technology, alongside the advent of relatively inexpensive (Davis, 2004) digital tools, has shifted the focus from traditional to contemporary types of stories, digital stories. Digital tools enrich the process of creating and telling stories by providing new ways to support story authoring and fostering new forms of creativity (Di Blas et al., 2009), as also illustrated in Chapters 4 and 10 (Mohamud, Buckler, Pitt, & Twining, 2022; Vogiatzis et al., 2022). Enriching stories with digital

tools entail many advantages, such as more variation than traditional methods in current practice; personalisation of the learning experience; making explanation or the practicing of certain topics more compelling; facilitating the involvement of students in the process of learning (Gils, 2005). There is no doubt that the affordances offered by technology are valuable, yet the tools used for the creation of a digital story are transitory; thus, the focus should be on the learning process than the tools with which students engage to create a story.

Sometimes, students are asked to produce a (fictional) story using written prompts, pictures, a wordless storybook, and videos (Pinto, Tarchi, & Bigozzi, 2018). Other times, students listen to a story and are asked to retell it at some later point (Pinto et al., 2018). Prompting students with a title, a picture, or not prompting them at all is a very common story-based technique that schoolteachers use. It is also a common research method to assess students' narrative competence and task-comprehension by asking them to tell a story (Gazella & Stockman, 2003), based on a single prompt.

Science stories differ from stories in the humanities in that they aim to improve the teaching and learning of science (Klassen, 2009). They are considered as a means of translating knowing into telling (Avraamidou & Osborne, 2009) and can prove useful in "communicating ideas and in making ideas coherent, memorable, and meaningful" (Millar & Osborne, 1998, p. 2013). However, it is often hard to accomplish the explanatory purpose in stories (Norris, Guilbert, Smith, Hakimelahi & Phillips, 2005), because of the need to use deductive-nomological explanations for scientific phenomena (Hadzigeorgiou, 2018). This chapter accepts the truth found in this limitation but stands by the view that science stories are not to be considered as a tool for testing concepts or explaining phenomena through experimentation and material evidence.

The purpose of a science story is to describe natural phenomena and physical behaviours through a set of sequenced events to help its audience makes sense of what, how and why a phenomenon happens. Some researchers view as a limitation the use of science stories as descriptive explanations presented in a narrative form (through the use of anthropomorphism), because they are more suitable for young children (Hadzigeorgiou, 2018). This chapter embraces the suitability of science stories, because they are "attractive modes of communicating science" (Avraamidou & Osborne, 2009, p. 21) to younger audiences, helping them to understand the science content in an entertaining and engaging way (Klassen, 2009).

Studies have sought to assess high-school students' conceptual understanding of specific processes (e.g., natural selection) through narrative-based interventions (Prins, Avraamidou, & Goedhart, 2017). While their findings provided valuable insight about how narratives facilitated students' understanding and engagement in a science lesson, their method focused on assessing students' performance after they were exposed to scientific information in narrative format, in comparison to other texts containing the same scientific factual information (Prins et al., 2017). Although it could occur that success or failure in a test situation accurately indicates cognitive development, it could also be inferred that such performance indicates nothing more than the student's ability to read the requirements of the test

(Adams, 2006). Thus, emphasis should be placed not only on the learning outcome (performance) but also on how students engage. Seeking to address this gap, this research placed emphasis on how students could engage in two different digital science-story activities.

Studying digital stories in science learning is of interest because science stories have become an attractive mode of communicating science (Avraamidou & Osborne, 2009). The story perspective on science is based on the fact that scientific theories are fundamentally story-like, in the sense that they rely on metaphors, analogies, and conceptual frameworks (Hadzigeorgiou, 2018). Stories are a conceptual tool for providing coherence, continuity, and meaning to its contents (Hadzigeorgiou, 2016), which makes them a valuable instructional tool, especially in the context of science education, where abstract knowledge needs to be presented in a way that makes sense to the students.

3.2 Literature review and purpose

The research documented in this chapter is concerned with how students engage collaboratively to prepare a digital story on a science subject they have already been taught. Collaborative learning settings encourage the construction of shared understanding through interaction with others, during which the participants are committed to or engaged in shared goals and problem solving (Dillenbourg, 1999).

A digital story can be presented in numerous ways. A story can be typed up as text, be performed, and videoed, be narrated and audio-recorded, be based on students' drawings and photographs, or combine various modes (Kucirkova, 2018). Authoring or editing a digital story does not necessarily require a new story. Students can author or edit an existing digital story by manipulating the presented information in it and determine its "order of presentation" (Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020, p. 2). Langley (1995) defined order effects as differences in performance that arise from the same set of material being presented to learners in different orders. Order is a fundamental feature of all stories because the order in which story events are narrated relates to their order in thought (Montfort, 2006). The order in which content is presented can "strongly influence what is learned ... and sometimes even whether the material is learned at all" (Ritter & Nerb, 2007, p. 3). There needs to be a strong relationship in the ordering of the content, because its presence among the story elements helps to determine the story's plot (Dettori & Paiva, 2009). The story elements do not have a life or meaning of their own; their "meaning is given by their place in the overall configuration of the sequence as a whole – its plot or fabula" (Bruner, 1990, p. 43). Thus, providing students with an opportunity to interact with the story content and determine its order – contrary to other instruction methods that do not allow interaction – by controlling aspects of its presentation (Hillmayr et al., 2020) provokes active thinking and supports meaning construction (Dettori & Paiva, 2009).

In science education, digital stories are often assessed as a project on their own. Students are required to produce and develop a story based on pictures taken with

digital cameras or found online, add subtitles and background, and present their story to their classmates (Hung, Hwang, & Huang, 2012). Results from such projects seem to improve “learning motivation, attitude, problem-solving capability and learning achievements of the students” (Hung et al., 2012, p. 376). Hung and his colleagues (2012) used an experimental study to provide valuable information about the use of digital storytelling in improving learning performance, but failed to evaluate how students might have engaged while working collaboratively. The current research sought to address that gap by taking an in-depth qualitative approach.

Building on this literature, the purpose of this research was to encourage students to actively engage in a science topic through collaborative learning and digital story creation. The science topic was chosen given literature pointing to the fact that matter is among certain topics considered as problematic for teachers and students, who find them hard to teach and learn, accordingly (Clough et al., 2013). The problematic nature of these topics is to a large extent due to students’ misconceptions and alternative concepts about matter (Hadenfeldt, Liu, & Neumann, 2014), which are almost the same across different culture, ethnic groups, and class backgrounds (Gregory, 2009). Within the last decade, however, the focus of research has shifted towards investigating students’ learning progressions for the concept of matter (Hadenfeldt et al., 2014), meaning attention has been given to how students conceptualise matter, to what extent they are able to explain everyday phenomena, or how they develop an understanding of matter over time (Hadenfeldt et al., 2014). Taking everything into account, it seems that the relation between digital science stories and students’ engagement in a problematic topic, such as matter, is still underexplored. To this aim, this research sought to engage students in a difficult-to-learn science topic through a creative process that could lead to deep understanding of the topic of matter which has been identified as particularly problematic. The research questions that guided the research are as follows:

- 1 How did students engage in each digital story activity?
- 2 How did students perceive each activity?

3.2.1 Research method and limitations

This chapter utilised a qualitative approach and focused on the design and evaluation of two digital science story activities and aimed at informing teaching practices. The two digital stories were the same in content but differed in presentation. Participants were two groups of primary students, aged 10–11 years old (Grade 5), who were taught the topic of matter two months before this research was conducted. For the purpose of the research, the researcher developed the two digital stories according to the curriculum material, while consulting with one of the Grade 5 teachers in order to make sure that the language and content were appropriate for the students’ age-level.

3.2.2 Data collection procedure

This research took place in a suburban public primary school in Athens, Greece. Two classes of students (middle-class, mostly white) aged 10–11 participated in this research. All students spoke Greek fluently. Class A consisted of 16 students and Class B of 15 students and all of them were described by their teachers as mixed-attainers, a statement that was also supported by students' monthly test results in science and other subjects. For the purpose of data collection, students from each class were grouped into small teams of three to four students and worked collaboratively. The two classes completed two different digital story activities on different days, during school hours. The first activity (named story sequencing) included a digital story about matter, broken down into fifteen scenes, which were presented to students in a random order. Students had to first determine the plot by ordering the story scenes, and then narrate it by making written commentaries. The second story (named story verbalisation) about matter was presented to students in its pre-defined order, as a complete story, and students had to narrate it by verbalising its content through written commentaries. Class A completed the story sequencing activity and Class B the story verbalisation activity. Neither activity included any audio or visual commentaries so that students could make their own narration.

The content of the stories was based on the curriculum material for the teaching of matter in Grade 5 and was the same in both activities. The ordering of the content in the story verbalisation activity was similar to the teaching sequence for matter taught at school, according to the Greek programme of study for science for Grade 5 (Figure 3.1). The proposed teaching sequence followed a hierarchical presentation of concepts, introducing first the simple concepts before moving on to the more complex concepts of which they are part. It started with an introduction to the three states of matter and then continued with the changes of conditions, such as melting and freezing, and evaporation and condensation. It ended with the concepts of heat and temperature.

Figure 3.1 The content of the story and its order of presentation in the story verbalisation activity.

Table 3.1 Data collected in response to the two research questions

<i>Data collected</i>	<i>Class A</i>	<i>Class B</i>	<i>Research questions</i>
Resultant stories	Randomly ordered scenes (story sequencing)	Pre-defined order of scenes (story verbalisation)	1 How do students engage in each digital story activity?
Group interviews	2 teams	2 teams	2 How do students perceive each activity?

The role of the researcher was to participate as a silent observer, keeping notes about the nature of students' interaction. With the students' consent, there were also audio-recorders to record each team's interaction. The Class A teacher was present as an observer and alongside the researcher offered practical and technical guidance where necessary.

After the two digital story activities were implemented, follow-up group interviews were conducted with a subset of teams of students from each class. The interviews with the students aimed at collecting information about students' perception of the conceptual nature of each digital story activity. The students were selected in such a way to obtain a representative group in terms of their abilities (medium attainers and low attainers), for which information was provided by their teachers. The research data for this research consisted of the students' resultant digital stories and group interviews, as outlined in Table 3.1.

3.2.3 Data analysis

Seeking to evaluate how students might have engaged through each activity, students' story elements were analysed according to the revised framework of Norris et al.'s (2005) framework for science narratives (Table 3.2). The group interviews were analysed using the hybrid process of thematic analysis (Boyatzis, 1998; Fereday & Muir-Cochrane, 2006). The hybrid process of combining inductive and deductive thematic analysis involved all the steps of the data-driven approach and at the same time allowed the researcher to use pre-conceived theories as a guide for articulating meaningful themes (Boyatzis, 1998). In the case of this research, the analysis started as data-driven, looking for patterns and themes in the data (Braun and Clarke, 2006). Attention was paid to basic concepts that recurred and parts of the data that described similar concepts were color-coded. Then the hybrid process progressed to theory-driven coding and analysis, drawing on codes from the revised science story framework of Norris et al. (2005). The compare-and-contrast phases of this process helped to minimise possible distortions (Boyatzis, 1998) and to overcome the possibility of the researcher biases in the qualitative analysis of one activity against the other.

Table 3.2 Key elements of a science story (adapted from Norris et al., 2005)

Story Element	Description
Purpose	The science story helps to understand the natural world and people's place in it.
Events	The science story events are chronologically related/sequenced, in an explicit or implied way.
Structure	The science stories are structured around two independent time sequences—the sequence of plot events and the sequence in which the events are related.
Agency	The science stories involve human beings or other moral agents who cause and experience events and are responsible for their actions.
Narrator	The narrator determines the point and purpose of the narrative and selects the events and their sequence. The narrator fashions a sequence of events into a significant whole.

3.2.4 Presentation of findings

The analysis of findings according to the science framework (Table 3.1) revealed that the two activities had a different conceptual nature. From the five essential elements, story sequencing (Class A) and story verbalisation (Class B) shared *purpose and agency*, while they differed in *events, structure*, and *narrator* (Table 3.3). Both classes provided scientific explanations about matter, which was the *purpose* of the science stories. Also, both classes involved *agency* in their science stories by attributing human-behaving or material behaviours to the story-characters. Where the two classes differed was in how they structured the story *events*, with Class A being free to sequence the story events, determining their chronological order and causal relation. In contrast, Class B followed the pre-defined chronological and causal sequence of events that were based on the proposed teaching sequencing for matter. Another key difference was in the element of *structure*: Class A's activity enabled them to sequence the story events based on how they related to each other, as opposed to Class B's activity that involved a sequence of plot events. Lastly, the role of the *narrator* was distinctively different through the two activities. Class A were free to determine the story plot by selecting the events that related and deciding about their sequence, whereas Class B determined the story plot by verbalising a pre-defined sequence of events.

In order to visualise the differences found in the story elements of the two activities, Figure 3.2 and Figure 3.3 illustrate the artefacts from two teams (Team A/Class A) and (Team B/Class B) that provide practical evidence of the conceptual nature of each activity. Regarding the element of *events*, Team A students determined the sequence of the scenes starting with scene 4, then scenes 3, 8, 14, 2, 1, 9, 10, 6, 7, 15, 11, 13, 12 and ending with scene 5. With reference to the element of *structure*, students followed a mixed ordering of the scenes. They started with the introductory concepts (scenes 4,3), moved to the changes of conditions (scenes 8,14), back to the introductory (scenes 2,1), to changes (scenes 9,10) again, then

Table 3.3 Analysis of students' resultant digital stories based on the five key elements for science stories

<i>Key elements of a science story</i>	<i>Story sequencing activity (Class A)</i>	<i>Story verbalisation activity (Class B)</i>
Purpose	States of matter	States of matter
Events	Free-choice chronological and causal sequence of events	Pre-defined chronological and causal sequence of events
Structure	Sequence of related events	Sequence of plot events
Agency	Humanlike agents and other entities	Humanlike agents and other entities
Narrator	Determines the story plot by selecting the events and their sequence	Determines the story plot by verbalising the pre-defined events and their sequence

Scene 4	Scene 3	Scene 8	Scene 14	Scene 2
Liquid is a natural state of matter. Liquids flow as their particles move around but they stay close to each other.	- Oh, the frozen lemonade has spilled over my face. - I know what to do! I'll use water to clean myself!	- I am going into the high temperature room - And I'm going into the low temperature room.	Mountains are snowy and cold. When the sun appeared, ice melted, and streams began to form.	Solid is a natural state of matter. Its particles move slightly while keeping their positions.

Scene 1	Scene 9	Scene 10	Scene 6	Scene 7
-Hi everyone! I play football very well! -I can also make a sculpture of myself as a king!	-Oh, no! My ice-cream is melting and the water with ice-cubes got really hot. This process is called MELTING. -Brrrr, it's so cold, 0°C and I am freezing! This	-Aaah, finally I'm out! Fresh air! -Oh dear! I've never seen so much cold before!	Gas is a natural state of matter. In gases, particles move around by constantly changing their positions.	Gases can occupy all space in these jars.
	process is called FREEZING.

Scene 15	Scene 11	Scene 13	Scene 12	Scene 5
Water evaporates due to the sun's heat.	Solidy goes into Greeny's bathroom and changes the room's temperature. First he turns it up and then he turns it down.	Particles are, first, turning hot and then turning cold.	Solidy swept the window with his hand because some gas had been condensed and turned into liquid. Then, an angry Greeny appeared but when he got closer to the window, he almost dropped his towel ... and so Solidy run away.	Gasy drank a liquid that made him burp ... so he scared Greeny, who dropped his liquid onto Solidy, who tripped over his sculpture.

Figure 3.2 Team A/Class A digital story (story sequencing activity).

introductory (scenes 6,7), then back to changes (15,11, 13, 12), and finished with an introductory concept (scene 5). Considering the element of the *narrator*, Team A engaged in a process of manipulating the learning content to match students' preferred presentation.

The story verbalisation activity, by contrast, involved a pre-defined story, with all its pieces together, and students had to narrate its plot by verbalising its existing context, as illustrated in Figure 3.3. The story verbalisation activity did not allow students to make their own decisions about the ordering of *events* or the *structure* of the story. Team B had to follow a pre-defined structure of events, starting with the introduction of the three states of matter in scenes 1–2, 3–4, and 5–7. Then, they continued with the changes of conditions, such as melting and freezing in scenes 8–10 and evaporation and condensation in scenes 11–12. They finished with heat and temperature in scenes 13–15. As such, the role of the *narrator* was that of determining the story plot by verbalising the pre-defined content (from scenes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 to 15). That is, through the story verbalisation activity students engaged in a process of verbally producing an existing content, presented to them as a complete story. Like with the story sequencing activity, students'

Scene 1	Scene 2	Scene 3	Scene 4	Scene 5
-Hello there! Hey, you fatball, make a trick using your solid football. -Ok! -Make a sculpture too! -Done!	In solids, particles do not move away from each other but they stay close to their permanent positions.	-Hmm, why doesn't this come out? -I have an idea! Yam!	In liquids, particles move away from each other but they remain close to their permanent positions.	-Oh, how nice! -Argh, I can't see! - Gloop, gloop (drinking the liquid)... oh no, my stomach...Brrrrrr! -Argh, my sculpture! I am going to 'kill' you!

Scene 6	Scene 7	Scene 8	Scene 9	Scene 10
In gases, particles move away from each other as far as possible.	Fire's particles are gases that spread out in a container, taking thus its shape.	-Mmm, my ice cream is so delicious! Luckily, I've got my ice cubes in case I get hot. Can't wait to go inside. -Let's go!	-It's too hot in here! Both my ice-cubes and ice-cream melt! This suggests that melting began. -Brrrr, it's too cold in here.. my water turned into an ice-cube. This means that freezing started.	-Taram! Ah, finally! -It was too hot! I melted! -I froze! -Here you go! -Thanks!

Scene 11	Scene 12	Scene 13	Scene 14	Scene 15
-Hmm, I am going in. -Lalala! Oh no, water evaporated! -Let's see here! A ha!	-Hey, you, come here! -Oops, that was close!	The thermometer is at 63 degrees Celsius. When an object gets hot, particles move faster. When it cools down, particles move slower.	When the sun is burning, it can make water evaporate in the mountains. The initial temperature is 0°C.	The sun is too intense and water in the yard evaporates ... and from liquid turns into gas.

Figure 3.3 Team B/Class B digital story (story verbalisation activity).

resultant stories from the story verbalisation activity were not compared to the original story, thus there was not a right or wrong plot.

Moreover, the analysis of the group interviews (Table 3.4) resulted in characterising students' perceptions of each activity's conceptual nature. These are presented below in a series of main assertions as those became evident in the data analysis: (a) some students felt that they owned the story sequencing activity more than the story verbalisation activity, (b) most students thought that each activity was enjoyable and exciting, (c) some students felt that story verbalisation was not as hard as story sequencing, and (d) some students were confused about the conceptual nature of story sequencing.

The first theme, *ownership of creation*, revealed that students liked the version of activity on which they worked, and felt they owned it in their way. Class A from the story sequencing activity liked the fact that they were free to order the scenes according to their own understanding and make commentaries about them. However, some students found this level of ownership hard. Unlike Class A students, Class B students from the story verbalisation activity were more excited about the way they owned their activity.

The second theme, *fun*, indicated that both Class A and Class B students enjoyed their activities, and they would like to do them again in other lessons. Class A students said that they had never before worked through similar activities. Class B students found it fun and expressed a preference over the story sequencing activity because story verbalisation was an easier activity.

Finally, the third theme, *conceptual complexity* revealed the complexity of the story sequencing activity's conceptual nature, which sometimes tired and confused students. The absence of visual or audio narration and the presentation of the scenes in a random order seemed to have troubled students. In contrast, students from the story verbalisation activity did not face such difficulties. As findings revealed, some participants showed a preference for easy tasks that did not require much effort. Further evidence from the group interviews' analysis showed that while both Class A and Class B students enjoyed their activity, the story sequencing activity as opposed to the story verbalisation one required harder thinking and more concentration, which tired some Class A students.

3.3 Discussion and moving forward

Chapter 3 explored how students might have engaged in collaborative learning and digital story creation in a science class. The story sequencing activity enabled students to actively engage with the learning content and to manipulate – to a certain extent – the presented information, determining their preferred order of their story. Interacting with the story content allowed Class A students to make their own decisions about the ordering and sequencing of the events, based on their understanding of matter. This process positioned Class A students as makers of the story, and involved physical and mental intensity, attention to detail and reflection. The physicality of manipulating and methodically arranging the story events so that they related and made sense, pushed students to think

Table 3.4 Open coding for students' perceptions of each activity

Perceptions	Ownership of creation		Fun		Conceptual complexity	
	Class A	Class B	Class A	Class B	Class A	Class B
	<p>S5: we had to first think about ordering the scenes and then invert the plot. This was a bit hard</p> <p>S3: I liked that we had to order the videos [scenes] in our own way and to make commentaries about them</p> <p>S2: I liked the fact that we had to make the commentaries</p>	<p>S2: we had to use our imagination</p> <p>S3: I enjoyed watching these videos and having to make the plot commentaries</p>	<p>S2: it was quite fun; we've never done it before</p> <p>S4: awesome</p> <p>S1: we should do it again in other classes as well</p> <p>S3: amusing</p> <p>S5: fun</p>	<p>S1: our activity was more fun I think, because it's very confusing when you have to order the scenes</p> <p>S4: I like animations, they are child-friendly, quite funny</p>	<p>S5: some scenes gave us a hard time and we got tired</p> <p>S1: we had to think harder about how to order the scenes and we didn't know where to start</p> <p>S2: because there were many scenes, it wasn't easy to figure out which scene goes where, which one goes first and so on</p>	<p>S1: it's easier having to only narrate the plot</p> <p>S3: our activity was easier, all the scenes were ordered</p> <p>S2: if we had the other activity, we would think harder and we would get tired at the end. I prefer ours</p>

not only harder but also differently, which is in itself a reflective meaning-making endeavour (Matthews-DeNatale, 2013).

The process of story making encouraged students to make decisions, think independently, and seek answers (Kucirkova, 2019). Decision-making as an explanation-based process, pushed students as decision makers to make sense of the available information to aid the selection process (Jonassen, 2011). Through story sequencing, students were required to make a choice among alternative claims and generate arguments to justify each option. It is through the process of debate, discussion, and reflection that students engage in the learning process, because they work together to storyboard and edit their digital stories (Standley, 2003). Students' decision-making depended on how they argued for and against each option on the basis of their existing knowledge and how they combined those arguments to reach a joint decision (Jonassen, 2011). Their final decisions resulted from the process of supporting or rejecting alternative claims/decisions and were constructed as an explanatory representation in story form that contained causal accounts of the evidence (Jonassen, 2011).

Positioning students as story makers not only enabled them to control aspects of the story presentation (Moreno & Mayer, 2007), and thus to take ownership of their creation, but also challenged their existing assumptions (Kucirkova, 2019). Engaging in the process of making a story depends on how one can see their understanding of something come together and make sense. The sharing of ideas and information allowed students to make meaning based on their collaborative interaction. The findings indicated that students strategically related scenes together, when they tried to conceptualise matter by matching together chunks of information based on their shared understanding and existing knowledge.

By contrast, findings from the story verbalisation activity pointed out the limited options that Class B students had when asked to determine the plot of a pre-defined story. Having to verbalise the content of the story, students did not have to reflect on either purpose or strategy in linking the science concepts between them. In particular, the story verbalisation activity allowed students to think about the content of the story, not its presentation/order, so students had to rely on retrieving and recalling prior knowledge. This process positioned Class B students as tellers of an existing story, which did not require any active engagement with the ordering of the content. Thus, the strategies of implementation that students followed in verbalising an existing story by determining its plot involved the effort to relate the story parts to previous knowledge. In doing so, Class B students might have tried to recall (parts of) content in the specific teaching sequence they were taught it. Such a sequence is dependent on teachers' and curriculum-developers' interpretation of how specific knowledge should be taught, what certain concepts should precede before others because without them any subsequent knowledge would not be comprehended.

Generally, both digital science-story activities involved a creative process that enabled students to determine either the story content and its plot, or its plot. Each activity had a different level of conceptual complexity involved. Taking

also into consideration participants' attainment level and previous knowledge in the specific topic, it was expected for some students from both classes to face difficulties in engaging with each activity. To conclude, the process of making a story as opposed to telling a story emphasised students' agency in making choices, thinking independently and seeking answers through shared understanding. The argument would be that engaging students in harder versions of the same task could generate better results (Brown, Roediger, & McDaniel, 2014), as students might learn more in the least preferred conditions (Kelly & Tangney, 2006).

3.3.1 Implications for practice

Positioning students as digital story makers gives them the opportunity to take responsibility for every step of the creation process while determining the presentation of the content and negotiating a shared understanding of ideas and information. Whilst students may find the story sequencing activity as conceptually difficult and at times tiring, it could be implied that challenging and hard activities deepen engagement and promote learning by doing, which is a meaning-making approach in itself. Activities that follow the proposed teaching sequence are not always beneficial in engaging students in science learning. The proposed teaching sequence depends on a hierarchical interpretation of knowledge, meaning that certain simple concepts need to be learned before other more complex of which they are part. It is often the case that the fragmented presentation of knowledge through a hierarchical teaching sequence can cause barriers to students' understanding of difficult-to-learn science topics. Therefore, using digital stories to communicate scientific information is valuable and should be further explored to investigate its potential for science teaching and learning.

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