Emergent stories written by children while coding: How do these emerge and are they valid compositions?

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Abstract: This paper extends our research into a novel Story-Writing-Coding engine, where Primary School children produce animated stories through writing computer code. We first discuss the theoretical basis of our engine design, drawing on Systemic Functional Grammar, embodied cognition and perceived animacy. This design aims to help children draw on the appearances of characters, props and scenery to evoke linguistic constructs leading to the emergence of stories. The second part of this paper reports on an empirical study where we aim to answer two research questions. First can compositions so produced be seen as valid compositions? To answer this question we conducted a linguistic analysis of coded stories and those written in an English classroom, and also using teacher ratings of these stories. Results indicate that while there are no significant linguistic differences between coded and English stories, coded stories are impoverished and should be seen as a first-draft to be revised in the English classroom. The second question was to probe our observation that while coding, children spontaneously told stories. Here we draw upon theories of embodied cognition and of perceived animacy. Our analysis suggests that these theories, taken together, help to explain the spontaneous emergence of stories.

Keywords: composition, coding stories, systemic functional grammar, grounded (embodied) cognition, perceived animacy

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1. Introduction

This paper discusses aspects of composing narratives or stories through a computer programming language (Java) using a Story-Writing-Coding (SWC) engine we have created. We have observed over 300 children composing a wide range of narratives including many stories. Early on in our research we observed that many children started to spontaneously verbalise their stories as they were being composed. Prior studies have looked at how coding can support idea generation (Price & Price-Mohr, 2018a), and at the actual processes of coding children use (Price & Price-Mohr, 2018b). In this paper we address two questions: First to what extent these coded narratives can be seen as valid compositions? Second, how can we explain the spontaneous emergence of stories?

A screenshot of the engine is shown in Figure 1; on the left is a box where the children type their computer code. When the play button is pressed the code is realised as an animation on the canvas to the right. Children select characters, props and scenery from a limited range provided, and progressively compose their stories while keeping an eye on the story as it unfolds in the animation. The example in Figure 1 shows the result of adding elements of scenery (the scarecrow), and two characters, Pip and Flup to the story-world. Example commands are shown to make Pip jump while Flup spins, then Pip says 'This is fun'. Children, working in pairs, typically add one or more lines of code; then press the 'run' button and view the effects of their code. They also have a paper sheet showing all the objects and code methods available. By the time they start story-writing-coding activities, they are very familiar with code methods and the effects these have on scene objects.

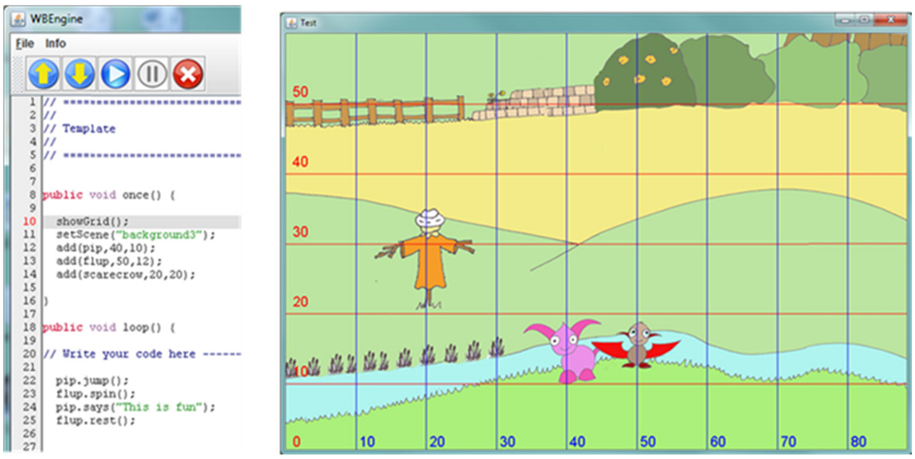

Figure 1. The user interface showing the code entry box on the left, with some example code; the right canvas displays a frame in the associated animated story.

A number of theoretical areas are drawn upon to ground our investigation and discussion: We draw upon cognitive science, in particular embodied (grounded) cognition, and also linguistics, especially Systemic Functional Linguistics. We also draw on theories of perceptual causality (animacy). These theories were fundamental to the design of the story-writing-coding engine and are discussed in the Theoretical Framework section below. We then discuss how this framework has been used to inform the engine design. The methods and then results of an empirical study designed to address our two research questions are presented followed by a discussion of these.

This study was conducted with one class of 26 children aged 7 to 8 years. Two example coded stories are presented in Appendix A. To avoid confusion, we introduce the following terminology. We refer to the story as it develops 'in mind', (unfolding through the animation), as the 'coded story'. Since we aim to compare coded stories with stories written in the English classroom, we asked children to write down their coded stories when complete, effectively transcribing the animation. We refer to these as 'written stories', and to stories written in the English classroom as 'English stories'. As explained in the Methods section below, we make a quantitative comparison between children's written stories and their English stories classroom in order to answer our first question.

2. Theoretical Framework

To understand how children compose and comprehend stories we need to draw on various areas of theory. First theories of cognition must be considered, since these help us understand how we make sense of the world. Then we must turn to linguistic theories in order to understand how to create meaning in composing stories. This also includes space and time which form the fabric of most narratives. Then we must consider theories of how ideas are generating during the composing process.

2.1 Theories of Cognition

Theories of text comprehension and composition have drawn upon various theories of cognition. Classical theories assume that knowledge is stored in semantic memory in symbolic or a-modal form (where details of perception and interaction are discarded) and processing of information proceeds using relations between symbols (Sadoski, 2018; Barsalou, 2008). Theories of grounded (or embodied) cognition propose that actual bodily experience in the physical world lays down mental representations of experience in the brain's modal system. These representations include perception (visual, auditory, haptic), action (movement) and introspection (mental processes), (Barsalou, 1999; Zwann & Madden, 2005; Glenberg, 2015). Linguistic theories also ground the syntax and semantics of language in experience such as reading and hearing, but also include motoric representations of typing, writing and saying. These experiences may lead to linguistic constructs that are syntactic in nature, effectively expressing a learned grammar (Zwann & Madden, 2005).

The two systems of perceptual representations and linguistic constructs are dynamic and reside in network structures that are interconnected where connections are learned through perceived spatial-temporal co-occurrences involving the body, the mind and the outside world. In other words there is a tight coupling between perceptual and linguistic domains (Zwann & Madden, 2005). Gibson introduced the concept of "affordance" that captures the relationship between perceived and actual objects and also the way in which the body interacts with the world (Gibson, 1979 p.94). Perceptions are guided by the anatomy and physiology of our bodies, as well as learned behaviours; e.g., a chair has the affordance of 'can be sat upon' but only for a human, not a mouse. A mouse may see the chair's affordance as 'can be run across'. In this way perceptual representations are linked to linguistic constructs. The affordance hypothesis asserts that what we perceive is needed to guide how we act (Glenberg, 2015). Next, the mechanisms of grounded cognition must be considered. In linguistics, Glenberg & Kashak (2002 p.558) propose the "Indexical Hypothesis" where sentence comprehension passes through three stages. First words and phrases that are read are indexed to referents in the physical world, as when an adult teaches a child to 'give me the cup' by pointing and gesturing. Second, affordances are obtained from these drawn-down referents, and third an attempt is made to coherently combine or 'mesh' the affordances, guided by the syntax of the sentence being read (Glenberg & Kashak, 2002; Sadoski, 2018). So indexing establishes what is being talked about, affordances establish how the individual can interact with the object (including any goals the individual has) and meshing combines affordances into potential patterns of actions that can be executed (Kashak & Glenberg, 2000; Glenberg & Gallese, 2011). The focus of Glenberg's theory is internalising motor activity based on the affordances of world objects, so that language acquisition becomes development of patterns of potential embodied action (Glenberg, 2015; Sadoski, 2018). Action-based comprehension results from a simulation of the linguistic content including action, perception and emotion.

Barsalou (1999) describes meshing as providing mental simulations of potential patterns of action. A mental simulation results from the activation of perceptual representations of experience together with words and the objects they refer to (Zwann & Madden, 2005). There is a plethora of possible simulations based on combinations of object affordances, linguistic constraints and the level of detail determined by the context (Barsalou, 1999). These are best understood as taking place within a dynamic system (e.g., a neural network) that will be attracted to a stable pattern that captures a particular understanding of the sentence being read. Meshing is a dynamic process that unfolds while clause-complexes (sentences) are traversed during reading that results in sensorimotor representations being activated which in turn activate associated linguistic representations (Zwann & Madden, 2005). As mentioned above these layers of representation are connected, leading to the mental simulation (Kashak & Glenberg, 2000; Zwann 2016). As an example, consider reading the clause 'The boat is on the lake'. This will invoke the affordances of the boat (can float) and of the lake (can be floated upon), these then mesh together and the clause makes sense. In comparison, 'The lake is in the boat' does not make sense since the affordances do not mesh with the clause meaning. Similarly 'The mouse is in the boat' makes sense, but 'The mouse is in the lake' is worrying.

2.2 The Linguistic Kernel

2.2.1 Brief Introduction to Systemic Functional Linguistics

Composing a story, whether through the English language or computer code such as Java, requires the author to make linguistic choices. To understand this process, we turn to Systemic Functional Grammar (SFG). Unlike structural approaches to grammar that specify how to write a sentence by assembling required parts, SFG provides a system of alternative choices and focuses on the creation of meaning. As Halliday reminds us: "A language is a resource for meaning making, and meaning resides in systematic patterns of choice" (Halliday & Matthiessen, 2014, p.23). Halliday suggests the three functions of language are to make sense of our experiences, to communicate and interact with other people, and to organise our language to fit in its context. Halliday refers to these as 'meta-functions', respectively *ideational, interpersonal* and *textual.* Narratives have a clear *interpersonal* dimension, i.e. a communicative purpose, to entertain, to surprise or to inform. They also have a clear *textual* structure such as a story (Propp, 1968). These two meta-functions are implicit in story-writing, therefore we focus on the *ideational* dimension, how meaning is created using language.

The basic quantum of text is a clause that has the generic structure shown in Table 1, presented with an example. Clauses can be extended or enhanced into clause complexes (sentences) that are further combined to create coherent text, discussed in the following section.

Table 1. The basic structure of the English clause

Pip	slowly	picked up	the shell
Participant 1	Circumstance	Process	Participant 2

Our world experiences consist of a flow of events that is captured in this clause structure with a *process* unfolding through time, involving *participants* and perhaps some qualifying information expressed as types of *circumstances.* Halliday provides a system of *process* choices intended to capture our outer experiences (of the world) and our inner experiences (of consciousness), that is mapped onto systems of *material* and *mental processes*. Material processes refer to verbs of action, mental processes include verbs of thinking, feeling, perceiving, desiring. Halliday introduces an additional *relational process* system that captures our ability to generalise. Together with *material* and *mental processes* these form the majority of clauses in English. See Table 3 for examples of various process types, discussed in the Engine Design section below.

2.2.2 Representing Time and Space

Narratives contain event chains, sequences of events that express how the story unfolds over time, or else through establishing causal relationships (Herman, 2002). SFG supports the expression of linguistic ideas of time using two main techniques: (i) clause complexing, where clauses are joined with a temporal operator, e.g., 'Grog went to the scarecrow when Pip arrived' (Halliday & Matthiessen, 2014, chapt. 7), (ii) through the use of the *temporal circumstance* of *location* e.g., 'Grog went home after the sunset'. A variation of (i) uses *conjunctive adjuncts* that retains distinct clauses, e.g., 'Then he fell off the log', (Halliday & Matthiessen, 2014, p.434).

The SFG expression of spatial experience through language is described by the *circumstantial* element of *location*. Typically this is achieved through an adverbial group or prepositional phrase (Halliday & Matthiessen, 2014, p.316). The SFG classification focuses on the *location* or *extent* of the action in space and also whether the action is at *rest* or in *motion* (Halliday & Matthiessen, 2014, p.317). This classification appears somewhat coarse, so we turned to the work of Landau and Jackendoff (1993) while consulting Close (1975, p.166-170), to flesh out the detail. Location involves two participants; one is to be located in relation to the other, the reference or grounding object. Typically the reference object is 'larger' or 'more stable' in the case of static location, or in the case of movement, the reference object is static while the object to be located is mobile (Landau & Jackendoff, 1993, p.225).

Our analysis has produced a complete SysNet that is shown in Figure 2. The first choice is static location versus movement. The location system is refined into systems of relative distance, direction and distance + direction. The difference between the last two is that direction implies a more general case e.g., *above* while distance + direction specifies the distance for a direction e.g., *on top of*. The movement system is developed into systems of direction and path dimensionality (point, line, plane, 3D-space). This SysNet can be used in a number of ways, for teaching grammar, for assessing text and in our case to inform engine design (see Section 3.2.2 below).

2.3 Idea Generation

When authors compose narratives, they write text, but always with an audience in mind, together with their own aims, perhaps to entertain, to explore, and to inform (Rietdijk, van Weijen, Jansen, van den Bergh, & Rijlaarsdam, 2018). Central to this is their generation of ideas, to express and communicate their intentions. There are many models of composition that we suggest can be situated along a cline. At one pole are models based on the information processing approach devised by Newell and Simon (1972) that focus on problem solving as a search through a problem space of abstract a-

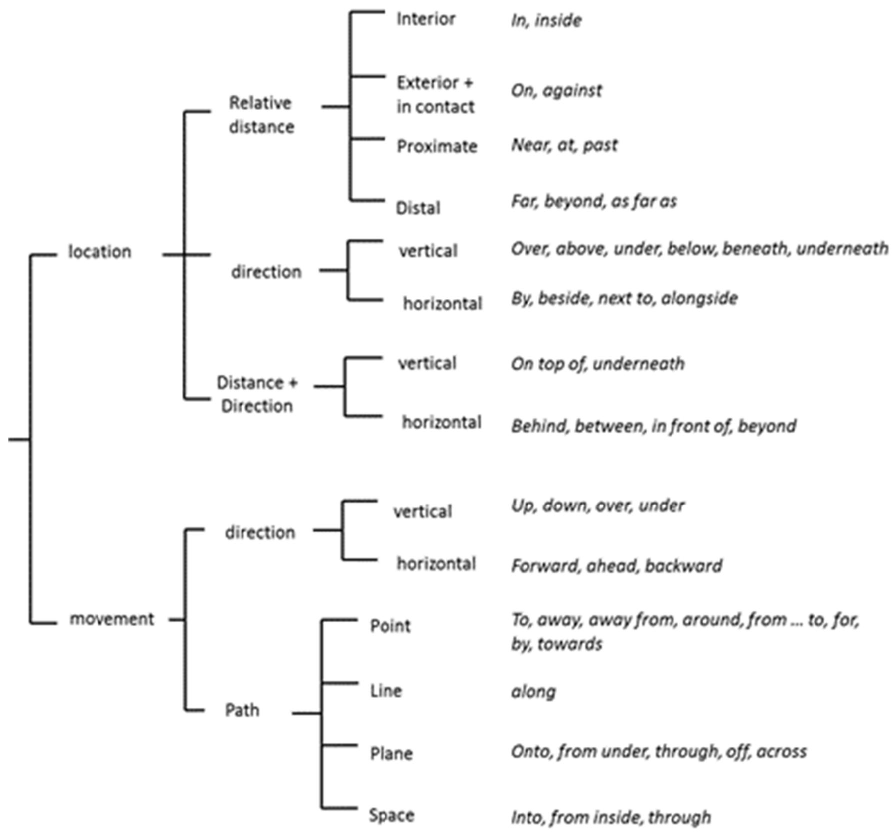

Figure 2. A system network (SysNet) that captures the range of circumstances of location.

modal symbols. Such problem solving lies behind the iconic Flower and Hayes (1981) and Bereiter and Scardamalia (1987) models, that discuss how cognitive effort is spent in processes such as planning and drafting to sort out the writer's existing ideas. At the other pole of the cline are models of the production of spontaneous writing or speech, such as Britton's (1982, p.110) "shaping at the point of utterance" model. Here the claim is that writers discover what they want to express only at the point of writing. The distinction between these two poles has long been recognised; Galbraith and Torrance (2004, pp.63-86) refer to writers as taking either a "planning" or an "interactive" approach. However, these models do not really address the creation of new ideas; rather they focus on retrieval and organisation of existing ideas from memory. This problem has been recognised by Galbraith (1999, p.139; 2009) who proposes the "knowledge constituting" model that involves the dynamic interaction between distributed semantic memory and distributed linguistic memory. The dynamics of this system, which includes feedback, is proposed to converge to the generation of the next new idea. While such a system is plausible, it does not specify the mechanism of truly novel idea generation. To this end we propose a new working model of idea generation drawing on Glenberg's (2015) indexical hypothesis discussed above where object affordances are meshed, guided by the grammar of written text during reading comprehension. We propose to invert this process, so that the meshing of object affordances (seen or remembered), together with memory traces of linguistic constructs, leads to the creation of grammatically correct clauses that express new ideas during the process of composition. Returning to the boat and lake example, we propose that when the authors view images of these objects, their affordances (can float on and can be floated in) are drawn into mind, and the clause 'The boat is in the lake' emerges. Idea generation is now driven by the potential of objects' affordances to be meshed, rather than random or associative recall of previous ideas. As more objects are added to the animation, the meshing of these objects becomes strong resulting in fewer possibilities to cohesively add more objects. This serves to focus the emerging story and direct it along a coherent path. As we have seen, affordances are managed by a SysNet that is also includes linguistic constructs and elements such as *processes* and *circumstances* that include space and time. Meshing therefore seems to be a good candidate for cognitively efficient generation of ideas while working 'at the point of utterance' to produce a coherent story.

In this section we have established a theoretical framework which we now carry forward to address the issue of our engine design. When this is complete we shall be in a position to explain our study and answer our research questions.

3. Engine Design

This section details the principles adopted in the design of the SWC-Engine. They are drawn directly from the theoretical framework presented in Section 2. First we establish a system network capturing the three engine design subsystems; linguistic resources, object affordances and the compositional process, here highlighting the role of the animation. Then we deal with the details of these subsystems in turn. It is important to understand the engine design, both as an application of the theoretical framework presented above, but also to make sense of the empirical study we conducted, reported in Section 4.

3.1 A Systemic Approach to Design

The design of our engine is inspired Hallidayan Systemic Functional Grammar (SFG) (Halliday, 2004; Halliday & Matthiessen, 2014). As already mentioned, SFG captures the structure of a linguistic system in the form of a system network or SysNet that identifies when choice is made between system components and also when components have to be considered at the same time. This design approach has been applied to other domains, such as visual design (Kress & Van Leeuwen, 2006), and visual narratives (Painter, Martin & Unsworth, 2014), though to our knowledge this is the first application to the design of a software system.

Our engine design SysNet is shown in Figure 3. Reading from left to right, the accolade groups three systems: linguistic resources, object affordances and processes, which must be considered at the same time. Each of these systems will be discussed in detail below, but first it is important to understand why they all are needed in the context of composing coded stories.

Central to this SysNet design are the linguistic resources available (Section 3.2 below). The engine must support the writing of a story (that unfolds in the *mind* of the author) which includes individual clauses containing a range of *processes* (verbs), e.g. movement and thinking. It must support *clause-complexing* e.g. combining clauses with 'and', 'then'. Clearly, time is important here and can be realised through a number of grammatical (and coding) devices. Also, attention must be given to the linguistic resources of space (e.g., prepositions) since the animation unfolds in space-time.

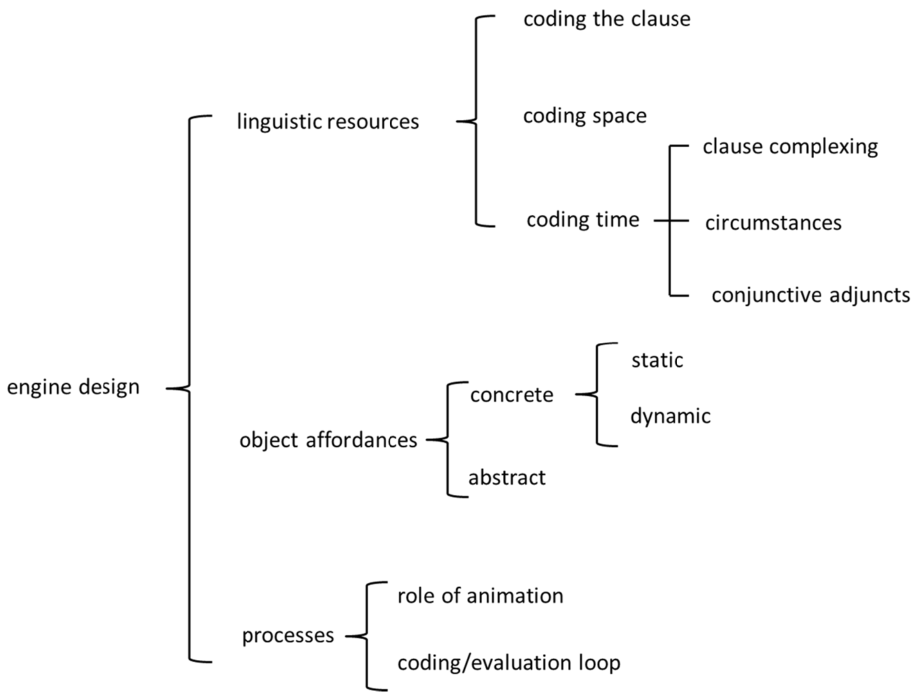

Figure 3. The engine design system network (SysNet) indicating all subsystems that must be considered together (accolades). Only the coding time subsystem is subject to three choices.

The coded story comprises a number of coded objects: characters, props, scenery and the canvas background. The *affordances* of these objects has been carefully considered with potential meshing in mind; some characters can walk, others can fly, and they may have the abstract affordances such as 'danger', 'benevolence' or 'magic' which authors may use in their composition. Affordances are central to this engine and are discussed in Section 3.3 below. Finally the engine design needs to consider the actual process of Story-Writing-Coding, especially the role of the animation in composition which is discussed in Section 3.4.

3.2 Linguistic Kernel

3.2.1 Clause Structure and Process Types

As mentioned in the Theoretical Framework, the basic quantum of natural language is the clause. The first requirement of the engine is therefore that it can map the structure of the clause onto a code statement. Table 2 shows how this is achieved; the code follows principles of 'Object-Oriented-Program' (OOP) design, where the participant is first stated (here 'pip') followed by the process (here 'pickup'), then any additional participant (here 'myshell') and an optional circumstance (here '2' specifying the time taken). OOP design is a powerful way of coding used by computing professionals.

Table 2. The general form of a statement of code, informed by the structure of the English clause, with example

Pseudo statement	participant1.process(participant2,circumstance);
Concrete example	pip.pickup(myshell,2);

Note the close correspondence between the clause structure and its realisation in the designed engine code statement. A summary of most of the coded functions is shown in Table 3, classified according to the *process* type. While many involve movement, as perhaps expected for an animation engine, characters can also see, think, speak and express emotions, all required for the composition of stories. It is evident that not all English *processes* can be coded; many are *mental processes* and no *behavioural process* is directly code-able. Nevertheless meaning associated with these *processes* can still appear in the coded story (as verbalised by the author, or present in the 'written story'); we refer to these as 'embellishments'. Such meaning can also be obtained by advanced coding techniques (Price & Price-Mohr, 2018a), but are rarely seen in compositions of children of this age. Most *process* affordances of the engine are *material* which reflects the distributing of process types in narrative text. The 'Moves To' processes operate in 2D space while the 'Moves At' processes execute at a fixed horizontal location. The 'Moves At' *processes* all work with circumstances of location

Table 3. A complete list of processes available as code functions, mapped onto some other English processes. 'C:' indicates a parameter of circumstance and 'P:' indicates a second parameter.

Material		
Moves To	walkto(C:location,C:speed)	ambles, saunters, strolls, trots, slopes
	runto(C:location,C:speed)	sprints, gallops, scurries, hurries
	flyto(C:location,C:speed)	
	hopto(C:location,C:speed)	
	leapto(C:location,C:speed)	
Moves At	jump(C:height)	
	spin(C:speed)	hovers
	rest(C:duration)	pause
Other	flip()	about-face
	grow(C:amount)	
	hide()	disappear, appear
	show()	
Mental		
Cognitive	thinks(thought)	thinks
		forgets, decides, imagines, understands
Emotive		likes, enjoys
Perceptual	cansee(P:object)	sees
		hears, feels
Desire		wants, craves
Relational		
Intensive	feels(emotion);	is, feels
		seems, appears
Possessive	pickup(P:object);	has, owns, gets, collects
	putdown(P:object);	loses, deposits
Verbal	says(verbiage);	says, asks for, tells
		speaks to
Behavioural		listens, looks, dreams, laughs
Existential	add(object,C:location)	there is
Causative		makes

(prepositional phrases) and many processes work with other circumstances playing the role of adverbials.

There are three important features of our engine design present in this table. The first concerns code coverage; all linguistic process types (with the exception of causative) are mapped onto code functions, so that all linguistic processes can potentially exist in a coded story. Second is the choice of individual code function words; they provide a clear and evocative meaning for the children. Third, while the lexicon of code words is quite small, each of these can map onto a large number of words in natural language. This one-to-many mapping is designed to allow the composition of rich and varied texts.

3.2.2 Representing Space and Time

As mentioned above, narratives consist of a sequence of events that unfold in time, many including causal relationships. This is a major factor in the engine design, where character actions can unfold either sequentially (Pip jumps then Flup spins) or concurrently (Pip jumps while Flup spins). In general time may occur in a narrative as an event at a particular time, e.g. 'Grog jumped' or over an extended time period, e.g., 'Grog was jumping during the rain'. Time periods are in turn bracketed by events demarking their start and end. Code coverage designed with this in mind is shown in Table 4, with examples, including the distinction between coding sequential and con-

Table 4. Alternative ways to code time: Example code shows how to produce concurrent or sequential actions for time seen as events and periods.

Actions	Code 'tuples'	Discrete time events	Time periods	Period start	Period end
Concurrent	pip.jump(); flup.spin();	and, but, however, when	while, when, whenever		
		Pip jumped but Flup spun.	Pip was jumping while Flup was spinning		
Sequential	pip.jump(); flup.rest(); pip.rest(); flup.spin();	then, before, after		before, from the moment	after, until
		Pip jumped then Flup spun		Pip jumped before Flup was spinning	Flup spun after Pip was jumping

current actions, using the 'rest()' function. Actions over time periods can be obtained by repetition of the action code statement(s).

Stories unfold through space as well as time; the engine provides a two-dimensional spatial canvas, though perspective can be obtained by judicious use of scale and speed, smaller and slower objects are perceived as being in the distance. The engine assets - actors, props and scenery have been chosen carefully to cover the SysNet shown in Figure 2 (above) that captures both the location and spatial movement of objects. These comprise (i) elements of the scene background; the meadow, the lake, a path, a bridge, a hill, sky (which can contain clouds), (ii) scene objects such as rocks, barrels, logs, kites, rugs, clouds and shoes. Working down the SysNet tree, first consider location. The lake affords being *in* while the shoe affords being *inside*. The rug affords being *on* (with contact necessary) and scene objects afford being *near*. Distal location, *beyond*, is afforded by areas such as the meadow. Vertical direction is afforded by the rug that can have objects *underneath*, the kite affords being *above* the ground and horizontal direction is afforded by scene objects that can be *by, next to*, and *alongside* other objects or characters. Direction with implied distance is afforded by being *underneath* some clouds, or *beyond* the meadow.

Turning now to prepositions expressing movement, the SysNet provides two choices, the vertical or horizontal direction and the dimensionality of the path. The hill affords characters moving *up*, the barrel affords jumping *over*, and characters themselves afford moving *forwards* and *backwards*. Objects and characters are conceived as points and afford moving *away, around, towards* other characters or objects. The path affords character movement *along* and the planar scene elements afford movement *onto* and *across* the bridge, *through* the meadow. The lake affords characters jumping *into* the lake, and light passing *through* the water. Of course the engine itself cannot suggest the actual prepositions to be used in composing the animated story (in mind) or transcribing it to the 'written story'. Yet the incorporation of elements identified in this SysNet may allow teachers to discuss prepositions, perhaps when the written stories are taken into the English classroom.

3.3 Object Affordances

In story-writing-coding, authors compose stories by selecting objects (scenery, characters and props), arranging these in space, and directing their actions in time. This requires designing engine objects with appropriate affordances that can be meshed in multiple ways to allow creativity. Some affordances can be seen directly in the images (Drax has wings so he can fly), but others are more abstract (Drax is a dragon, so he can be malevolent). We propose the affordance design SysNet in Figure 4. The first division is into concrete and abstract affordances, e.g., Drax the dragon can fly, but he also represents danger. Concrete affordances can be static and dynamic. Static affordances comprise *circumstances of manner or quality,* e.g., Drax is large and red, and *circumstances of location* e.g., Drax is usually flying in the sky; the boat is usually in

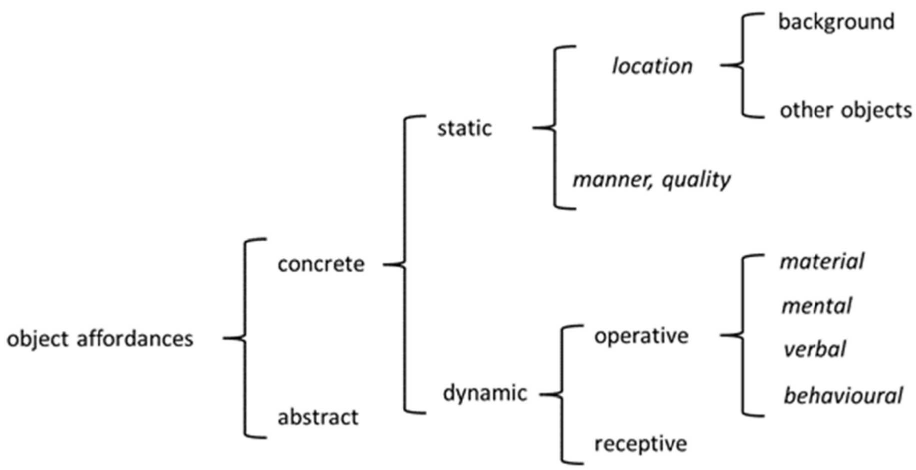

Figure 4. The design SysNet of object affordances. All components of this SysNet must be considered together.

the lake. Dynamic affordances parallel SFG's organisation into different *process* types and whether the affordance is operative, what it can do, or receptive, what can be done to it. Pip can sit on the rug; the rug can be sat upon. Returning to the static affordance of *manner or quality*, it is possible for a static image to convey the impression of movement. Kress and Van Leeuwen (2006) in their analysis of the grammar of images suggest that time may be depicted in a single image if a component contains an implied 'vector'. This could be a character with one foot located off a platform, indicating an imminent fall. Painter, Martin and Unsworth in their book 'Reading Visual Narratives' (Painter, Martin & Unsworth, 2014) provide some vectored images that suggest actions associated with *material, verbal* and *mental processes*. We chose not to include vectored images since this could bias the use of other affordances in composition.

The affordance SysNet has clear similarities with SFG linguistic SysNets, e.g. see Halliday and Matthiessen (2014, p.65, p.229) for examples. As an example of an application of this SysNet consider the example objects shown in Figure 5. Perhaps the most interesting affordances are abstract that could be triggered by authors″ previous experiences of text, media and life. Pip and Flup appear benevolent and so does Drax. However, having the form of a dragon suggests he can also be malevolent. The rug can be seen as a magic carpet or as a place for a picnic, the fire suggests danger and the flying saucer suggests an alien world. All these affordances could prime a particular story-type. Objects suggest affordances of location in various ways. Relative to the scene background the flying saucer would normally appear in the sky, as may Drax; other objects would normally appear on the ground.

The affordance of walk or run-to can be seen in all characters, (who have feet), the winged Flup and Drax show they can also fly. Characters have other material affordances such as 'pick up', 'carry', 'leap', mental affordances such as 'think about', 'believe', 'desire' and verbal affordances such as 'say', 'discuss'. The other objects have a more restricted affordance set; they certainly have no mental or verbal affordances.

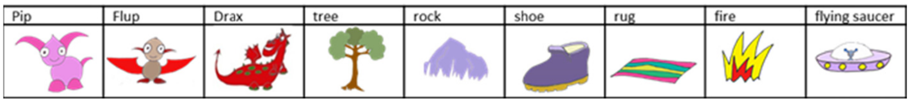

Figure 5. A small selection of characters and other scene objects to give some indication of their affordances.

The fire can 'spread' and we could agree that the flying saucer can 'fly', though it may be more accurate to cast this as the receptive 'can be flown'. There are various other receptive affordances, the rug can be 'picked up' and 'put down', but the rock and tree are fixed firmly in the ground, and it would be unwise to move the fire. Everything can burn, (receptive 'be ignited'), except the rock, and the fire; finally everything can 'be thought about' or even 'be talked to'.

3.4 The Role of Animation

Our engine design SysNet (Figure 3) places the 'role of animation' within the 'processes' system since it is a part of the *locus of composition* where ideas, expressed through code, and connected in mind, can be tested, explored and changed. The animation canvas provides the medium through which authors can visualise their developing stories and execute the meshing process. It also acts as externalised working memory. We propose that the basic quantum of animation follows from the 'tuple' of code statements that express movement through space-time, both sequential and concurrent. For two characters there are six different space-time quanta shown in Table 5.

Table 5. Tuples of space-time motion for two characters. Time runs from top to bottom, distance between the characters is shown on each horizontal axis.

Both characters resting	One approaches the other	Both approach each other	One flees	Both move apart	Both move together

In terms of narrative theory, these tuples can be considered as events, while combinations of tuples into 'patterns' can be considered as event chains (Trabasso & Sperry, 1985). Such chains can be temporal or express reason or cause. Evidence from children's coded stories do reveal such chains, but they reveal much more, the attribution of human behaviour ('animacy') to the characters, such as dancing, chasing, or rescuing, which can be implied, or explicitly coded by more proficient authors. It is almost as if watching the animation produced 'so-far' provides momentum to move the story forward.

To understand perceived animacy we draw upon the literature investigating 'the perception of animacy'. The pioneering studies of Heider and Simmel (1944) and Michotte (1950) showed that simple geometric shapes in motion were perceived as animate; observers attributed emotions and personalities to these objects by virtue of their motion. As Tremoulet and Feldman remark (2006, p.107), "We unconsciously seek to explain observed motion and we attribute animacy when the explanation involves a mental cause". For a review of current research see Scholl and Gao (2013) and Parovel, Guidi and Kreb, (2018). Perceived animacy of a single object may be induced by a change in speed or direction (Scholl & Gao, 2013). When several objects are moving, forms of social interaction may be perceived such as chasing, avoiding, fighting, and playing, (Tremoulet & Feldman, 2006).

We suggest that perceived animacy which taken together with the zoomorphic appearance of the characters, and their other visual affordances leads to a strong mental experience of time, cause or reason which flows naturally into the developing stories. At each stage in producing the coded story, the author experiences animacy which directly brings the character to life and has a feeling of momentum that leads to composition at the 'point of utterance', and may well explain the spontaneous emergence of stories when children first start to learn to code.

In summary, the engine design has been informed by the theoretical framework discussed above, providing linguistic resources, realised through statements of code, to allow natural language to be associated with code statements. This is based on Systemic Functional Grammar. In addition objects have been designed with affordances to support the process of meshing as proposed by theories of grounded cognition that we suggest help understand the generation of ideas during composition. Since the coded stories unfold through space-time, the engine design specifically considers how space and time can be coded, and in turn, how these relate to the linguistic kernel. The role of the animation as naturally helping the dynamics of composition has been suggested.

4. The Study

The study was designed to test our two questions: First to what extent these coded narratives can be seen as valid compositions? Second, how can we explain the spontaneous emergence of stories?

Children in this study were drawn from a mixed Year 3&4 class in a small rural school. There were 26 children (11 boys and 15 girls) with mean age 7 years 10 months, and standard deviation 7 months. The study was conducted in the children's usual classroom in school, not a laboratory setting. The children worked in pairs to encourage them to discuss and peer-review each other's work, according to principles of "authentic writing" (Rietdijk et al., 2018, p.643). Children experienced 12 60-minute sessions led by the researchers with the class teacher observing and helping. The children were told that this was a research project looking at 'creating stories through computer coding' and that their work was to be highly valued, in accordance with the University Ethical Approval policy. The first 8 sessions were devoted to learning to code using guided discovery, though the use of tuples was taught. This was followed by 3 story-writing-coding sessions where the children were asked to code an animated story. They were encouraged to 'make-up' an original story and were not given any story prompts, but were told that they could code a familiar story if they preferred. The final session was devoted to testing aspects of affordance meshing.

When they were satisfied that their coded story captured the story they had developed 'in mind', they were asked to write this story down in English; we refer to this as the 'written story'. This enabled us to answer our first research question, to compare these written stories with compositions they had written in an un-related English class, 'English stories'. Six children were unable to code a narrative or even a recount, (their animations comprised un-connected events), and so were excluded from the study.

We compared the written stories and the English stories in two ways. First we made a *linguistic* comparison between these two story-types looking at the processes employed and how time and space were used. This comparison was motivated by the linguistic basis of our engine design; we were in effect probing whether or not the engine provided a rich enough linguistic basis to allow the composition of stories. Since only 11 English stories were available, we hand-coded a sample of 11 stories of each type. Due to the small sample size we used the Wilcoxon Rank Sum test to evaluate linguistic feature differences between the story types. Second we recruited two experienced primary school English teachers (not involved in the classroom activities) to evaluate to what extent both the written stories and English stories could be viewed as true compositions according to their expectations working with children of this age. Scoring was holistic, looking for evidence of story structure, character development, the use of dialogue, engagement, and appropriate linguistic devices, drawing on their professional judgement. Two examples of stories and teacher evaluations are reproduced in Appendix A. The sample contained pairs of written stories and English stories for each child. Stories were scored on a scale 1-10. After checking for inter-rater reliability we used the Wilcoxon Signed Rank test to test for any significant difference between the ratings of both story groups.

To answer the second research question 'How can we explain the spontaneous emergence of stories?' we created a final classroom session, when the story-writing-coding activities were complete. Children were presented in class with 5 static scenes comprising a few scene objects and were asked to write down 'what happened next'. They would be familiar with this activity since images (single or a sequence) are often used as story 'prompts' in English classes. Barthes (1977) refers to some images as providing for an expectancy of what comes next; Lessing (Lessing in Bernstein, 2002, p.125) refers to such images as providing a "one single moment of action, and must therefore choose the most pregnant, from which what proceeds and follows will most easily be apprehended". An investigation using pregnant images, conducted by Shen and Biberman (2010) reports that viewers saw temporally and causally related events in these images, and also higher-order narrative features such as the complicating and resolving of events. Three of the scenes presented were expectant and two neutral, the former were intended to encourage meshing, the latter two were not. Since these scenes were static, the element of perceived momentum was not present as a confounding variable.

5. Results

5.1 Linguistic Features

The results of the Wilcoxon Rank Sum Test, intended to uncover any linguistic differences between coded and English stories are shown in Table 6. Since multiple measures were made on the same data set, these have been corrected using the Holm variant of the Bonferroni correction (Holm, 1979) to avoid the familywise error increasing beyond the 0.05 significance level. Here the *p*-values for each test are ranked starting with the largest and then the corrected significance limits are calculated as 0.05/rank. It is against these limits that the *p*-values are compared. The results are classified into (i) process types, (ii) how time was represented and (iii) how space was represented. The measures for process type were expressed as fractions of each process against total processes. The measures for coding time and space were expressed as fractions of the total number of clauses in each story.

The results show that there is no significant difference between linguistic devices used in written stories and English stories, which suggests that written stories (which reflect the stories contained in the animation) and English stories make similar use of English grammar. This is perhaps unsurprising, since the same children are writing both story-types. It is also interesting to look at the distribution of linguistic elements used. Looking at processes, the distribution of processes is similar to those found by Lewis (2014) for children of this age, except for mental processes where the 17% of mental processes we found is almost double the values reported by Lewis. Looking at coding time, the main devices used in clause-complexing were sequencing (then, when, after, soon) or concurrent (and, but, while). Time was also expressed through circumstances of manner such as 'too fast', 'immediately', 'suddenly', 'slowly'. There was very little use of Conjunctive Adjuncts in the both written and English stories which suggests these children were not familiar with this device.

Children made use of prepositions of location and movement in both written and English stories with about the same effect. Looking for clause-complexing for reason or purpose in the written stories revealed that 9/11 stories made use of these devices.

Table 6. Comparison of linguistic features between written and English stories

Process	Median written	Mean written	Median English	Mean English	W	p	rank	α' (0.05/ rank)
Material	0.44	0.45	0.37	0.40	115.5	0.31	6	0.0083
Mental	0.15	0.17	0.20	0.20	75	0.40	4	0.0125
Relational	0.16	0.16	0.18	0.18	87	0.78	1	0.05
Verbal	0.08	0.08	0.11	0.12	54	0.10	9	0.0055
Behavioural	0.08	0.08	0.08	0.09	81.5	0.59	3	0.0167
Existential	0.0	0.022	0.0	0.01	77	0.36	5	0.010
Coding Time								
Clause Complexing	0.15	0.17	0.25	0.25	35.5	0.007	11	0.00455
Circumstance: Time	0.15	0.17	0.22	0.24	44	0.02	10	0.005
Conjunctive Adjunct	0.0	0.04	0.06	0.06	63	0.14	8	0.00625
Coding Space								
Prep: Location	0.17	0.19	0.17	0.17	104	0.64	2	0.025
Prep: Movement	0.14	0.15	0.19	0.18	68	0.24	7	0.0071

This is encouraging, since the engine does not directly support expression of reason or purpose. In summary, written stories which are transcripts of coded animations show no significant linguistic differences from stories written in an English class. We suggest this provides evidence that story-writing-coding can be viewed as *bona fide* composition, at least from a linguistic perspective.

5.2 Story Comparison

From the class, 11 coded and 11 English stories from each child were obtained; all were scored by two raters, (experienced primary school teachers not involved in the classroom activities). The inter-rater-reliability was calculated according to the intra-class correlation (ICC) Hallgren (2012) metric, that yielded ICC = 0.78 which indicates good reliability (Koo & Li, 2016). Scores for each child were then averaged; the groups of coded and English stories were compared using the Wilcoxon Signed Rank test. The scores for the English stories (Mdn = 8.0) differed significantly from the coded stories (Mdn = 5.), V = 3.5, $p = 0.03$, $r = 0.52$. The effect size is large, and indicates that coded stories were judged to be of significantly lower quality. This result was supported by the raters' general feeling that the coded stories were 'often clunky' or of 'low quality'; they specifically mentioned the paucity of strong (fronted) adverbials, and lack of devices of cohesion. There was an exception where one coded story was rated at 9.5. No coded stories were rejected as compositions. These results are hardly surprising since coded stories were produced in a class focusing on coding and not on the literacy techniques explored in the English class. Despite coded stories appearing impoverished, we suggest these could be seen as a first draft in the composition process, or as a storyboard, and taken forward into the English class for revision. Doing this would help to validate the need to teach text revision in a classroom setting.

5.3 Testing Affordance Meshing

Affordance meshing is central to our working model of composition, that we propose is a major influence behind the generation of new ideas leading to the spontaneous generation of stories. To test this proposal, we presented five static scenes, described in Table 7 to the whole class on the whiteboard. They were asked to 'write down in your books, what happens next?' They were given around 30 seconds to do this before the next scene was presented. The scenes were chosen to be independent of each other, and we found no evidence of children carrying forward their responses to previously presented scenes. Not all children were able to provide a response for all scenarios; the ratios presented below are relative to the number of children who responded to each particular scene.

For each scenario we coded each response according to the *action* reported and categorised the codes. Looking at all the responses and the categories together, it was clear that certain categories were common to the responses. Based on this analysis we chose to record a category where at least 30% of the children mentioned it. In all scenarios except the fifth two categories emerged.

Children in the first scenario (expectant) imagined either saving the Robin (7/21) or focusing on the fire, which was reported as either spreading or being extinguished (12/21). Children who imagined the consequences of the fire were clearly meshing the affordance of the fire to spread, and of the tree to be ignited.

Table 7. Summary of 'What happens next?' static images presented to the children, either neutral or expectant.

1.	An injured Robin is perched in a tree with fire blazing under the tree. Two other characters look on appearing distressed. The background is a meadow with hills and a lake.	expectant
2.	Class-teacher is standing in a road in front of some houses. A carpet is also on the road, some distance from the teacher. Teacher and carpet are in colour, against a greyscale Manga background.	neutral
3.	Pip is standing on a tall stack of eight barrels located in a meadow with a stream.	expectant
4.	Pip is approaching a bridge over a river. A troll is peeping out from under the bridge.	expectant
5.	A cluttered Christmas scene with eight characters in the snow in front of a bridge over a frozen river with a church in the background. The characters are facing the reader.	neutral

Those who imagined the fire being extinguished meshed the affordance of the lake to provide water, and the affordance of water to extinguish the fire. Children who focused on meshing the affordance of the injured robin with that of the fire underneath, together with the affordance of the characters to fly imagined the rescue situation.

Children in the second scenario (neutral) imagined either a picnic (7/23) or a journey on a magic carpet (8/23). Here the use of colour for the teacher and the carpet focused the children's attention on these. Some saw the carpet as having the affordance of location, a picnic. Others saw the affordance of motion, a magic carpet. Meshing the affordance of the teacher to be upon something, with the affordance of the carpet to support something led to these alternative imagined events.

Children in the third scenario (expectant) imagined that either Pip fell and was injured (11/24) or that she was saved (6/24). They recognized the affordance of a stack of barrels to be unstable, the affordance of the height of the stack to provide danger, and the affordance of Pip to fall and the meshing of her falling and landing on the ground. Some imagined the fall and its consequences, while others recognised the immediate danger, that Pip had the affordance of 'can be saved' and imagined a rescue.

In the fourth scenario (expectant) the children were almost equally divided between imagining the Troll capturing Pip (10/24) and Pip escaping (9/24). In all cases they saw the Troll's affordance of 'being dangerous' and meshed Pip's affordances with this, of 'can be captured', or 'can run away'.

The final Christmas scenario (neutral) did not produce any categories with 30% or more membership. The most common reported ideas included having a party (4/22), dealing with presents (4/22), playing in the snow (3/22), singing (2/22), and decorating something (2/22). This is a consequence of a complex scene containing objects that could not easily mesh with each other and the background. However, the Christmas background seems to take on a privileged role where its affordances do provoke appropriate language.

In summary, these scenarios were designed to test our proposal that affordance meshing could lie behind the spontaneous emergence of stories. The fact that most children could immediately think of what happened next for the expectant scenarios, (their reactions to the neutral scenarios was observably slower) suggests that meshing could be at work here. The existence of clear categories of response across the group of children also suggests that affordances are directing the generation of ideas towards these categories, and not to some random, non-causal or non-coherent response. We suggest there is good evidence for our proposal, although clearly more work needs to be done here.

6. Discussion

We have proposed a theoretical basis for understanding and analysing coded stories created through the medium of computer code, focusing on elements of linguistics and modern theories of cognition. This framework has been applied to the design of the story-writing-coding engine as well as to the analysis of the code stories (expressed as 'written stories') produced by children, and comparing these with stories composed in the English classroom ('English stories'). Evidence from both linguistic analysis and teacher-evaluation strongly suggests that coded stories can be seen as valid compositions, but with the caveat that the associated 'written stories', while capturing the stories children had 'in mind' could be viewed as first drafts in the formal compositional process, that could be taken into the English classroom and refined. This could support both the statutory teaching of English grammar, and the revision element as part of the process of composition, but in a way that is meaningful and motivating for our young learners. We find it interesting that the majority of coded stories included reason (cause) or purpose. This answers our first question.

Turning to the second research question, we propose that one reason for the spontaneous emergence of stories while coding can be traced to a process of affordance meshing tied into linguistic constructs. Stated simply, when children choose various related images, the image affordances evoke language. As a second reason we suggest that perceived animacy is a vital factor in coding stories; the author sees their animation 'so far' and this gives them a feeling of momentum to develop their story, moreover to compose 'at the point of utterance'. This may well help explain the spontaneous emergence of stories when children first start to learn to code. Taken together, we suggest these reasons lead to a strong mental experience of time, cause or reason that flows naturally into the developing stories.

We therefore suggest that story-writing-coding is a useful intellectual activity for primary school children; as well as learning to program a computer, it offers opportunities for teachers to work across the curriculum, and provides some benefit for children's learning about composition. There are of course some limitations to our work. While our sample size was small, (but mitigated) it does remain small, and our findings should inform larger scale investigations. Further explorations on affordance meshing and perceived animacy need to be made. Also, our research needs to focus on the linguistic dimension, especially our discovery of the relatively large number of mental processes to material processes encountered. Nevertheless, there are clear implications for Primary Schools. This paper has not focussed on the Computing curriculum, but rather the English curriculum. It seems that coding stories can contribute to the English curriculum in a significant way, inspiring the generation of ideas in composition and fostering creativity. It can also situate statutory requirements of teaching grammar and also the drafting and revision of texts, but in a meaningful and not contrived way. Children love being creative, they love telling stories. We do not suggest story-writing-coding will 'liberate' them from formal approaches required, but rather will enthuse them to engage with classroom activities.

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Appendix A

Here we present two examples of coded stories in their transcribed form, 'written stories', together with teacher evaluation shown in italics.

Story 1

Once upon a time, there lived a young dog called Spot. He lived by himself in a small hut. One day Spot decided that he wanted to go on an adventure. So Spot packed his things and he was on his way. Spot had travelled a long way but then he stopped by a small pink castle. Then a fairy popped out of the castle "Hello, what's your name?" asked the fairy. "My name is Spot, what's yours?"

"My name is Anabelle. Let me show you my castle". So Anabelle showed Spot her castle. They soon came out. "Would you like to go on an adventure with me?" asked Spot. "Yes please!" So off they went side by side to keep each other company. They went through forests, they went through cities. Anabelle even took Spot over a rainbow!. Soon they got onto a boat and went for a swim. Spot swam safely to land but he didn't notice … Anabelle was drowning! Anabelle shouted and shouted for Spot but he didn't hear her for the waves were too loud. "Come on Anabelle, hurry up!" But then Spot noticed what was happening. Spot jumped in the water and tried to save Anabelle but the current was too strong. After a few tries Spot finally reached Anabelle. Spot carefully put Anabelle on his back and swam to land. Spot slid Anabelle off his back. Anabelle lay there still on the ground and Spot watched her. Anabelle suddenly fluttered her winds. Spot smiled with relief. Anabelle was still alive! Anabelle slowly opened one eye then the other. Anabelle smiled at Spot and said "Thank you".

"It's OK" replied Spot. So they went all the way back over the river, all the way back over the rainbow, all the way back through the cities and all the way back through the forests until they reached Anabelle's castle. "Thank you for taking me on the adventure. I had great fun".

"It's OK" said Spot. So they said their goodbyes and Spot headed back home. "Well that was an adventure wasn't it! See you next time!"

Reviewer 1 Grade 9/10

A really good story! Good description, good variety of connectives (and, but, [in order] to, for, until), adverbs and a range of punctuation. Plenty of action and a good storyline maintained and linked throughout the writing. I may be being picky but I would just like to see some longer sentences in the middle section. I was very engaged as a reader.

Reviewer 2 Grade 10/10

Excellent structure, where the characters are first introduced. There is drama, tension and resolution. The use of dialogue is well thought-out. Good use of story-telling vocabulary and style.

Story 2

Drax the dragon has set fire to the egg. Pip feels sad and starts to panic by jumping up and down. Grog sees pip and hops over to see what is wrong. Grog sees the fire and becomes worried too and also starts to panic. But then both stop and get an idea. Pip runs back and then jumps on the egg putting the fire out. Both grog and pip then are happy and glad that the egg is safe.

Reviewer 1 Grade 5/10

Essentially the author has a classic story plot here. There is a problem, a climax (the idea will save the day) and a resolution. Lots of action words are used: 'jumping', 'hops', 'runs' and 'jumps' which somehow add to the feeling of panic (maybe unintentionally) that the fire is causing. The references to emotions strengthen it and I engaged with the story more because of this. Possibly capital letters have not been used for names throughout? Punctuation is limited to full stops. This story is asking to be developed!

Reviewer 2 Grade 5/10

This story is short, but it has a good structure with some character development and drama. There is no dialogue and no real effort to tell a story.