Digital storytelling teaching robotics basics

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Abstract. Digital Storytelling (DST) is a powerful tool for teaching complex concepts. DSTs are typically used in the humanities but several papers have shown that they are also a wonderful tool for the sciences because they are more involving, contextualized and can easily lead to deeper understanding. In the classical use of DST the story is the content, while the digital medium is the way of telling it. Our approach is slightly different: the story is not the content but a glue for the main contents, while the digital medium remains the way to tell the story. We propose the use of DST as a means to teach surgeons the basics of robotic surgery, by using a story that should be involving for them, i.e. a surgical operation, within which we will illustrate specific concepts on robotics in surgery.

Keywords: Digital storytelling, robotics, training

Introduction

The technical literature suggests that learning must be designed starting from a constructivist approach which encourages students to learn in a social context, to develop the ability to create new knowledge, and to solve new problems by employing creativity and critical thinking (Hoffman, 1997; Mergendollar, 1997; Richards, 1998). Spivey (1997) indicated that constructivism views students as constructive agents and views knowledge as built instead of being passively received by students, whose ways of knowing and understanding influence what is known and understood.

Usually, theoretical information is taught through academic lectures, which can be highly demanding for trainees in terms of cognition and attention. If the trainee needs to learn concepts concerning a field that is distant and very different from their own background, the cognitive and attention resources required are definitely superior compared to the resources required to learn an equally complex concept, but within their known topics.

Classically Digital Storytelling (DST) can be defined as "a modern expression of the ancient art of storytelling. Throughout history, storytelling has been used to share knowledge, wisdom and values. Stories have taken many different forms. Stories have been adapted to each successive medium that has emerged, from the circle of the campfire to the silver screen and now the computer screen" (Sadik, 2008).

The particular nature of DST involves several sensory channels and a multitude of cognitive processes which harness the conventional linguistic way to other, less common, forms of expression, such as spatial, musical, interpersonal, intrapersonal, naturalist and bodily-kinaesthetic ways, but which allows for a more comprehensive understanding of a problem and/or situation (Sadik, 2008). This extensive involvement of sensory channels and cognitive processes is possible thanks to the use of the digital medium, allowing a greater immersion in the story and a greater attention to the contents than normal, only auditory, storytelling.

Barrett (2006) found that DST facilitates the convergence of four learning strategies centred on students:

- student engagement

- reflection for deep learning

- project based learning

- effective integration of technology into instruction.

The DST movement was founded by Joe Lambert and the late Dana Atchley. From this movement in the late 1980s the Center for Digital Storytelling in Berkely, California was born (Center for Digital Storytelling, 2012). This organization has, since the early 1990s, provided training and assistance to people interested in creating and sharing their personal narratives.

This organization provided the Seven Elements of Digital Storytelling, a fundamental starting point to begin working with DST:

1. Point of View - What is the main point of the story and what is the author's perspective?
2. A dramatic question - A key question that keeps the viewer's attention and will receive an answer by the End of the story.
3. Emotional content - Serious issues that come alive in a personal and powerful way and connect the story to the audience.
4. The gift of your voice - A way to personalize the story in order to help the audience understand the context.
5. Soundtrack power - Music or other sounds that support and embellish the storyline.
6. Economy - Using just enough content to tell the story without overloading the viewer.
7. Pacing - The rhythm of the story and how slowly or quickly it progresses.

Main typologies of DST concern personal events, historical events, or want to teach about specific scientific fields (Robin, 2006), but DST is not limited to these fields.

DSTs are stories told through a technological medium, but it is considered very important that the story is in the foreground while the technological medium is in the background (Bull & Kajder, 2008). Ohler (2006) stresses the importance of building a storyboard or a story map in order to develop an effective DST. According to Ohler, the essential components of DST are:

1. A call for adventure – the need to solve a specific situation.
2. Problem solution involving transformation – the situation that has to be solved requires a transformation, which can happen in different ways, including skill acquisition, maturation, learning and self-discovery.
3. Closure – The story comes to a meaningful conclusion, involving the main character's realization of something significant.

Ohler (2006) clearly thought about biographical DSTs, but these three principles can be used to teach any kind of concept.

In the rest of our paper, we present a short introduction to DST and its principles, we give a short review about how these principles are applied and we describe DST's main field of application.

The several fields of DST application

DST technique has been applied to several fields of knowledge. Its use in social studies is well known, because it develops students' understanding of democratic ideals, cultural diversity and participatory citizenship, improves their communication skills, motivates them to learn about the past and the present and creates a class bond through shared experiences (Bull and Kajder, 2008).

An interesting application of this idea was the study by Cianciolo, Prevou, Cianciolo and Morris (2007) that used DST's to stimulate a discussion among military professionals to stress and to explore the effects and possible solutions of a negative attitude towards the local population in a peace-keeping scenario in a foreign country, in this specific case Iraq.

DST is often considered exclusively applicable to arts and humanities, but research indicates that it is also a wonderful instrument for the teaching of mathematics and science.

In his book, Schiro (2004) explained how he used digital storytelling to teach students algorithms and problem solving through several learning stages. He argued that digital stories, with other materials such as worksheets, can not only present the mathematical skills that students need to learn, but also situate the mathematics in a context that is interesting, engaging and relevant. Papadimitriou (2003) suggested that digital storytelling can be used to teach computer science and programming to a wider and more diverse audience, indeed DST has also been used to teach software engineering in university courses (Rao, 2006).

With regard to the field of medicine, DST has mainly been used in the teaching of values and attitudes, for professional development and interpersonal communication enhancement (Borkan, Miller and Reis, 1992; Hensel and Rasco, 1992; Mayers, 1995; Rabinowitz, Maoz, Weingarten and Kasan, 1994; Terry, 2012). However, there have been situations in which DSTs have also been applied to medical knowledge learning (Bizzocchi and Schell, 2009; D'Alessandro, Lewis and D'Alessandro, 2004). D'Alessandro et al (2004) proposed a DST for third year medical students, developed following these educational objectives:

1. Tell individual memorable stories from real patients in their own words.
2. Emphasize the clinical problem faced by patients and their families and de-emphasize the disease the patient has.
3. Promote primary care principles (e.g. safety and health screening)
4. Written primarily at the level of the introductory paediatric clerkship for third year medical students.
5. Used for independent study by medical students locally and nationally (i.e. not as part of a specific course).
6. Take a limited amount of time for students to work through (approximately 20–30 minutes).
7. Take a limited amount of time to author the story.

The DST template prepared following the above principles was structured in the following way:

1. The patient's story, evaluation process and clinical course told through the patient's own voice and a clinical narrator.
2. A problem-based approach to the evaluation of the patient's problem, including differential diagnoses, history, physical examination, laboratory and imaging evaluation.
3. A discussion of the patient's disease process based upon journal articles.
4. A brief conclusion and follow-up told through the patient's own voice.

In this short paragraph we have given a short review of the main fields of DST's application, focusing on medical and scientific applications. Starting from these works, in the next section we will describe our proposal based on additional theoretical issues.

Our proposal

DST can also be defined as the use of the technological/digital medium to tell stories in order to share knowledge, values and principles.

Our approach is slightly different, while in the classical approach the story is the content to learn, in our approach the story is a structure to pass contents. We found this approach in the consideration that stories are an excellent medium to transfer knowledge even if the concepts are not directly connected to the story's theme, for at least three reasons:

1. *Stories contain chronologically organized information*, harnessing the natural structure of our mind which favors episodic data, namely information about real-life experiences coming from external sources (Visser, 1996).

2. *Stories are a glue for information*, they can connect a concept with a particular point of history, like the famous mnemotechnique of loci, thus easing memorization (DeBeni and Cornoldi, 1985).

3. *Stories ease the formation of mental images*, learners who were instructed to create mental images of events in sentences learned two to three times as much as learners who repeatedly read sentences aloud (Anderson, 1971).

According to Barrett (2006) conceptualization, classical DST can be graphically represented as in Figure 1, while our proposal can be represented as in Figure 2.

For example, if we want to teach a child the six-times table, we can propose a DST about six small frogs. In this story each frog eats two flies for a total of twelve flies, after that they jump three times for a total of eighteen jumps, and so on. In this way the young student is engaged by the story, the important data is episodically organized, each number is connected with a particular aspect of the story (frogs, flies, jumps …), and it's easy to form mental images about each part of the story.

Therefore, the original conceptualization of Bull et al. (2008) where in DST the story is in the foreground while the technological medium is in the background, is reformulated so that in our approach both story and technological setup are just a channel for the teaching of specific concepts. In this manner, obviously, it is not possible to try teaching concepts in an implicit way, we have to highlight them, so that it will be clear to trainees which concepts are important to be learned.
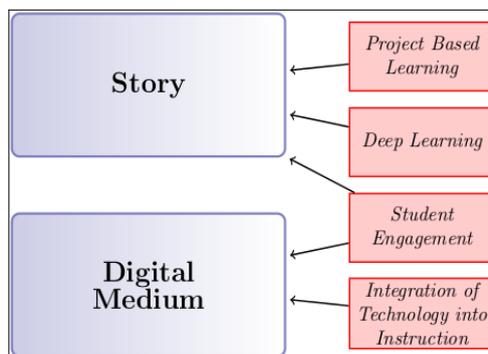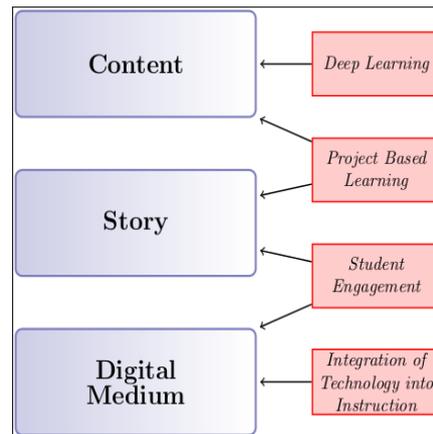

Figure 1. Classical DST according to Barret conceptualization

Figure 2. Our proposal according to Barret conceptualization

The highlighting of a concept is an important phase, because it's necessary to extract the concept from the narrative stream, by interrupting the narration, the soundtrack and possibly also by using a different graphical style, in order to give trainees the required time to recognize and memorize the concept, before returning to the narration.

Following our proposal we will design DSTs for surgeons using an involving story as a glue for important concepts. By considering the students taken as the target, the story will be a hypothetical surgical operation, with well-defined characters thought to ease the possibility to empathize. Each important content will be linked with an important phase of the story, in order to have concepts episodically organized and highlighted with a pause of the narrative flow. Main concepts to be inserted in the DST are summarized in the Table 1.

Two applications of our proposal

In this section we describe two examples on how, starting from Table 1, we can design story maps which will be useful for introducing participants to robotics concepts. In the first example we want to use DST to introduce concepts of robotics to surgeons, in the second example we show how this approach could be used to introduce robotics to a different kind of audience.

Table 1. Concepts to teach through DST

Area	Concept
General Robotics	• What is a robot • …
Surgical Robotics	• Differences among open, laparoscopic and robot-assisted surgery • Advantages/Disadvantages of robotic surgery • Typical surgical theatre for robot-assisted interventions
Specific of the robot	• The console • How to control the robot • Emergency button (if any) • Indexing (if any) • Movement scaling (if any) • Zoom (if any) • … • Emergency functions (if any)
Troubleshooting	• …

Introducing Robot-Assisted Surgery to Surgeons

Before starting to write the story map, we need to know specific features about our audience, such as their medical specialization, their experience, their motivation, the main topics we want to explain and how long could the DST be.

If we suppose that our audience consists of urological surgeons, we should use as a background story (the glue) an impactful story about a risky urological operation, in order to get their attention and involvement. It is very important to consider other characteristics of our surgeons in order to choose the main character and the language used in our story. For example if our audience is mainly formed by young residents, the main character should be a resident of a similar age, the language can be less formal and in line with the knowledge acquired, and we can introduce some elements of computer use. Instead, if our audience includes more experienced and elderly surgeons, the main character should be a surgeon with similar experience and the language should not include very complicated technical words. A clarifying example of story map is reported in Table 2.

Table 2. Illustrative story map about robotic surgery

Phase	Description	Concepts explained	Purpose
Introduction	*Introduction of main characters:* • the protagonist • a first surgeon "wise tutor" through whom the main concepts will be explained • a second surgeon • nurses and technicians • In the this first part we should answer some questions such as: • Are there special relationships among them? • How do they know each other? • Is there a specific reason for the main character to learn how to do a surgical operation? • *Introduction of the patient* • The disease should be serious and presented with emphasis • It could be useful to briefly introduce his/her family to improve the engagement		Engagement and involvement of the audience
Use of robot-assisted surgery	The protagonist is introduced by the "wise tutor" to the robot definition and to its several advantages	• What a robot is • Differences among open, laparoscopic and robot-assisted surgery • Advantages/Disadvantages of robotic surgery	Teaching general concepts

Table 2. Continued

Phase	Description	Concepts explained	Purpose
Robot preparation	The surgical team enters into the surgical theatre, and the first and second surgeons explain to the protagonist general issues about their surgical robot-assisted system.	• Typical surgical theatre for robot-assisted interventions • The console	Teaching specific concepts about a surgical robot-assisted system
Use of robotic system during interventions	During the operation, the surgical team explains how to use the robotic system in a specific way	• How to control the robot • Indexing • Movement scaling • Zoom	Teaching specific concepts about surgical robot-assisted system control
Emergency functions	Unexpectedly during the surgical operation there is a complication. In this phase the story increases suspense, but the problem is easily solved through the robot emergency functions used by first and second surgeon	• Emergency button • Emergency functions	Teaching how to use the emergency functions of the surgical robot-assisted system
Happy ending	The surgical operation ends in the best way		Engagement and involvement of the audience

Introducing Robotics Concepts to High School Students

High school students are a very different kind of audience in comparison to surgeons and residents. Obtaining their involvement becomes more and more important for their learning process. It is crucial to think about the optimal characteristics of main characters and we can include more fiction in the story, without forgetting the educational content. For this reason, in order to guarantee students' involvement and to point out that robotics it is not only for male students, the protagonist is going to be a girl of the same age as the audience. Supposing we wish to prepare a DST in order to pre-teach, and also to promote, the use of robotics prior to a robotics course. In this scenario it is not necessary for the robot presented in the DST to be the version that will be used in the course or, even, to be a real robot. In Table 3 an illustrative example of a story map is reported. In this example the robot will be a fictional device and the story will describe its use in the collection of waste in a polluted park.

Validation procedure

In order to understand the feasibility and the supposed advantages of DST methodology in comparison to a classic lecture scenario, we propose an experimental paradigm. The main goal of this experimental paradigm is to demonstrate that the DST methodology allows for the better memorization of concepts after a single lecture, in this instance we utilized a delay of three days, without homework or home study, than a classical frontal lecture.

Methods

A group of students, numbering at least 20 people matched for gender, age and cultural background, have to be randomly assigned to two, equally sized groups, the experimental (which will be taught by a DST) and the control one (trained by a classic, frontal, lecture).

Table 3. Illustrative story map about robotics basis for high-school students

Phase	Description	Concepts explained	Purpose
Introduction	Introduction of main characters: • the protagonist • the teacher "wise tutor" • a co-protagonist already expert in the use of the robot In this first part we should answer to some questions such as: • Are there special relationships among them? • How do they know each other? • Is there a specific reason for the protagonist? • Introduction of story topic • The polluted park		Engagement and involvement of the audience
The robot	The protagonist is introduced by the "wise tutor" to the robot definition and to its several advantages	• What a robot is • Concept of master and slave • Advantages/Disadvantages of robotics application	Teaching general concepts
Using the robot (1)	The co-protagonist shows how to drive the robot, while the teacher gives some explanations about actuators, locomotion systems and control systems.	• Actuators • Locomotion systems • How the control system works • ...	Teaching specific concepts about actuators, locomotion systems and how to control them
Using the robot (2)	The protagonist uses the robot, facing complex situations and giving the story some suspense. During the story, concepts already presented will be recalled.	• Previously seen concepts	Recall already presented concepts. Engagement and involvement of the audience.
Happy ending	The park is no longer polluted.		Engagement and involvement of the audience

The contents of the DST and classic lectures have to be the same and presented in the same order, to guarantee that the supposed effect is given by only the differences in the presentation, and not by the complexity of the explanation or the quantity of arguments touched upon. In order to evaluate the quantity and quality of the information retained by the two groups two multiple choice questionnaires will be prepared:

1. A 10-item questionnaire for the immediate evaluation.

2. A 20-item questionnaire for the long-term evaluation, with the same 10 questions as the first questionnaire (old questions) and 10 new questions.

Table 4. Results

	DST Group		Classical lecture Group	
	Student A	Student B	Student C	Student D
First Questionnaire	9	9	10	8
Second Questionnaire – Old Questions	9	9	9	9
Second Questionnaire – New Questions	10	7	5	4

The first questionnaire will be administrated to both groups immediately after the lecture (classical or DST), while the second questionnaire will be administrated after three days. Both questionnaires will be answered separately by each participant, and evaluated by two independent blind evaluators. Possible differences in the evaluations will be checked by a third independent evaluator.

The results from the first questionnaire will be compared between groups to check if there are differences in the immediate mnemonic abilities.

The results from the second questionnaire will be compared by separately considering the old questions with the new questions.

The comparison between the old questions is necessary in order to check if the two groups are equal in long time memory, because answering the first questionnaire questions is an additional elaboration of the notions taught by the lecture, that could overlap to notions learned by the DST or the classical frontal lecture.

Finally, in order to check if there is a specific effect of the use of DST or a classical frontal lecture on what is learned, we will compare the results in the new questions between groups.

Results

Up until now we have collected data from four students, two of them attended a classical frontal lecture and two of them a DST lecture on basic robotics for robotic surgery. All the subjects are fourth-year students in medicine at the University of Verona, all of them are males aged from 23 to 24 Y.O. The experimental data is presented in Table 4.

The little amount of data does not allow for the execution of proper statistical analyses, but it is possible to observe an initial trend that, if it does not change, with a greater sample will reach the statistical significance.

Conclusions

This paper has focused on the main issues needed to prepare an effective DST for introducing surgeons to the basic concepts of robotics. Surgeons may not be familiar with robotics, nor with other high-tech concepts. For this reason, an academic lecture about robotics could be very demanding and discouraging for them.

In order to lower the cognitive load required to attend the lecture, and to capture surgeons' attention, DSTs present optimal characteristics. In the first part of this work we affirm that traditionally DSTs have been considered limited to the humanities, but there have been

successful experiments involving the teaching of software engineering in university courses and of pediatrics to medical students.

The typical conceptualization of DST highlights the story; therefore DSTs are mainly used to teach a story. The approach presented here is slightly different; the story is not the content to learn but a glue for several contents. In this way it is easy to put together concepts from a field (in this case, from robotics) in a story concerning a different field (in this case, surgery). The advantages of this approach are many: there is the possibility to link unknown concepts with known concepts, and these connections could be chronologically organized; characteristics that are typical of the most famous mnemotechnique, the loci method. Moreover this approach eases the formation of mental images, another feature that is shared with most mnemotechniques.

In this paper we have also proposed an experimental methodology to validate the DST approach, and we have shown some data. The data shows that the two groups have an equal short term memory, as the scores from the first questionnaire demonstrate. Moreover, it is also possible, from the old questions in the second questionnaire, to observe similar long term memory. Finally and more importantly, we have shown, in accordance with our hypothesis, that DST improves the retention through time of the notions heard in a single lecture.

DST's are teaching tools that answer several pedagogical principles; they are useful for teaching concepts of various levels of complexity. As it is possible to observe from our examples, our approach to DST is not limited to the teaching of robotics, it is a proposal that could be applied to many knowledge fields notwithstanding their complexity, and they could be especially useful with students whose age ranges from 12 years old to adulthood, when abstract reasoning has to be formed, according to Piaget's influential model (Piaget, Gruber, and Vonèche, 1995).

Acknowledgments

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