2-2019

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Recommended Citation

Albano, Giovannina and Iacono, Umberto Dello (2019) "Designing digital storytelling for mathematics special education: an experience in support teacher education," *The Mathematics Enthusiast*. Vol. 16 : No. 1 , Article 13.

DOI: <https://doi.org/10.54870/1551-3440.1458>

Available at: <https://scholarworks.umt.edu/tme/vol16/iss1/13>

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Designing digital storytelling for mathematics special education: an experience in support teacher education

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Abstract: In this paper we present and discuss a designing experience carried out by prospective support teacher. They have been introduced to digital storytelling methodology and they are required to design story-problems in mathematics, devoted to support students with disabilities. Story-problems have been analyzed with respect to the narrative dimension and mathematical correctness. The teachers, who worked in groups, have been able to design and implement striped problems, i.e. stories with a deep integration between the mathematical and narrative aspects. However, most of the groups showed difficulties in creating well-posed problems from a mathematical point of view.

Keywords: digital storytelling, Context and Demand model, support teacher education, mathematics education, disabilities

Introduction

This paper reports a pilot experience of prospective teacher training, devoted to mathematics education for students with disabilities, based on the use of digital storytelling. The experiment has been carried out in the course “Codes of the logical and mathematical language” within the Special Education Laboratory, at the University of Molise, in the South of Italy.

Literature shows that storytelling is a methodology that fosters learning and develops problem-solving skills (Haven, 2000) and it can be used as a very effective tool in mathematics teaching and learning, also for introducing hard concepts (Zazkis & Liljedahl, 2009). Moreover, as Bruner (1986) formerly noted, narrative thinking constitutes a formidable resource for the development of logical thought, thanks to the complementarity between the two kind of thinking and the centrality of narrative

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thinking in everyday life. For what concerns Special Education, Jacobs & Fu (2014) showed that the use of digital storytelling, modern version of storytelling, allows students with disabilities to gain confidence in their own abilities and to develop writing skills and abilities in the use of technology.

The narrative thinking, therefore, should play an important role in mathematics education and special education. However, to make this synergy between logical thinking and narrative thinking really effective in problem solving, the narrative part and the logical one need to be appropriately connected, as shown by Zan (2011).

Within the above theoretical framework, the pilot was conceived as a creative workshop. The teachers were asked to design a striped problem (Zan, 2012) within a digital storytelling, focused on a mathematics problematic situation to be solved by a student with certain disabilities. The prospective special education teachers involved in the pilot were ordinary second grade secondary teachers, with various curricula background, mainly not mathematics-specific.

As the prospective support teachers in the pilot comes from various curricula and they attended lectures showing both digital storytelling methodology and its relation with mathematics education (Zazkis & Liljedahl, 2009; Lambert, 2002; Petrucco et al., 2010; Mannin, 2010; Skouge & Rao, 2009; Michalski et al., 2005; Zan, 2011; Zan, 2012), the outcomes of the workshop has been analyzed from various lens:

1. how much does the curricular background of prospective support teachers rely on the effective design of striped problems with respect to the narrative fractures between context and question?
2. do the story-problems designed by the prospective support teachers propose questions mathematically correct?

A further goal concerns the beliefs of the teachers with respect to effectiveness of the storytelling and digital storytelling methodology for students with learning difficulties or disabilities. It has been investigated by means of a questionnaire. In the following, after a description of the theoretical framework on storytelling and digital storytelling in education, with particular reference to special education and mathematics education, we present the pilot, for what concerns the methodology, the outcomes and the related discussion.

Theoretical framework

Storytelling e digital storytelling

Storytelling is seen as one of the oldest forms of human art and is the first conscious form of literary communication (Shedlock, 1951). According to Burrell (1926), it is the natural way of teaching. Storytelling can be defined as the art of using language, voice, physical movement and gestures to show the elements and images of a story to a specific audience (Haven, 2000). According to Haven, there are various benefits of using storytelling as a teaching tool: development of reading, writing and language skills, help in memorizing information for a long time, powerful interdisciplinary tool, support for motivation, self-confidence, creativity, and problem-solving skills. Baker and Greene (1987) argue that the narrative has a positive effect on the cognitive and social development of the child and the storytelling allows children to understand motivations and models of human behavior and helps them overcome psychological problems. Bettelheim (1976) states that fairy tales enrich children's lives, stimulate their imagination and help them to better understand their emotions and to recognize their limits to find solutions to problems.

In mathematics, storytelling is an effective tool to introduce hard concepts in an engaging and easily internalizable way, it brings a human element in a discipline often perceived as sterile and arid and creates an atmosphere of entertainment in the math classes. Stories can be used in mathematics for different purposes: creating a framework for problem solving, creating interweaving between problematic situations, introducing hard concepts, explaining or asking questions (Zazkis & Liljedahl, 2009).

Digital Storytelling (DST) (Lambert, 2002) is the modern version of storytelling that makes use of various types of multimedia: audio, video, hypertext, images and so on. Many studies show the benefits of DST in education, both for teachers and students (Sadik, 2008; Robin, 2008; Barrett, 2006), also in mathematics (Albano & Pierri, 2016; Albano, Dello Iacono, Mariotti, 2016; Albano, Dello Iacono, Fiorentino, 2016; Dello Iacono, 2015; Starcic et al., 2015; Gould et al., 2010; Inan, 2015; Schiro, 2004), because it allows the development of skills in real, meaningful and involving contexts, and allows the integration between logical and narrative thinking (Bruner, 1986) which, if well calibrated, is very effective in education (Zan, 2012). Storytelling and DST are very powerful tools also in a special and inclusive didactics, for students with learning difficulties or disabilities (Michalski et al, 2005; Manning, 2010; Botturi et al., 2014, Aiello et al. 2013) and for teacher training (Skouge & Rao, 2009, Heo, 2009). Jacobs & Fu (2014) observe that writing digital stories has allowed Julia and Tyrone (two pseudonyms of students with learning difficulties and speech impairment) to improve writing, reading and developing digital skills. However, there are few experiences reported in the literature concerning digital storytelling for inclusive and special mathematics education.

Effectiveness of story-problems in mathematics

It is a widespread practice in mathematics teaching to embed mathematical problems within a real or imaginary story, assuming that such familiar or everyday context helps the student in the process of problem solving. Data from research, as well from practice, shows that it is not always true, and in some cases the story context can even hinder him. Zan (2011; 2012) identifies, as a possible cause of this phenomenon, the presence of narrative fractures in the formulation of the story-problem, i.e. the presence of break points between the mathematical structure and the narrative dimension. In order to avoid such fractures, a close link between the context and the mathematical question is needed. So the story can act as support to understanding of the question and, therefore, to the solution process. Conversely, when the question does not arise spontaneously from the context, that is the narrative information are not related to the problematic situation, then the story can hinder the solution process (for examples and more details see Zan, 2012). On the other hand, if the narrative part dominates the mathematical problem, the pupil can be get too much engaged by story and she can neglect mathematical consistency.

Zan (2012) introduces the C&D model (Context and Demand) that we report in its original version in Figure 1:

Figure 1: C&D model proposed by Zan (2012)

The C&D model highlights the main features of a story-problem text in order to be effective in evoking suitably student's knowledge for supporting, instead of hindering, the problem solving processes. It concerns only recommendations on the narrative dimension of a problem, assuming an already identified and correct mathematical structure. We can distinguish three key elements of the story: at least a character, a goal to be achieved by the character, a question whose answer helps the character to achieve her goal.

Methodology

In this section we describe a teaching experiment carried out at the University of Molise, within the course “Codes of the logical and mathematical language” of the Special Education Laboratory. The course lasted 20 hours, divided into three lessons held on consecutive days, respectively of 5, 10 and 5 hours. The course was attended by 17 prospective support teachers, most of them not graduate in mathematics, with teaching experience in first and second degree of secondary school. All of them had already knowledge on teaching methodologies for special and inclusive education.

The lectures was devoted to

- introduction (face-to-face 5 hours lecture) prospective support teachers to theoretical references concerning the special mathematics education research (Locatello & Meloni, 2007) and storytelling and digital storytelling methodologies in mathematics (Zazkis & Liljedahl, 2009) and to web environments to be used for the learning activities, such as the free online environment Toondoo (www.toondoo.it) to create digital comics;
- workshop session (10 hours laboratory), where the prospective support teachers were asked to realize a digital storytelling in mathematics, for a single student with disabilities or for a group of students, including one or more of them with disabilities;
- final discussion (face-to-face 5 hours lecture), concerning the prospective support teachers presentation of their products.

For the workshop activities, the participants were split into four groups, each of them composed by teachers of different domains. Three groups were composed of 4 members and one of 5 members. Each group had at least one laptop with connection to the Internet.

The workshop session was equipped with some guidelines, consisting in the following requests:

1. to select a class with a disabled student M;
2. to briefly describe the diagnosis of M, focusing on her logical-mathematical difficulties;
3. to choose a mathematical content and to devise a concerned striped problem, in order to support M in the solving process;
4. to implement the striped problem into a digital storytelling

Moreover, the prospective support teachers were required to reply to a questionnaire, consisting of the following open questions:

Why do you guess your proposal is effective for the disability at stake?

Why do you guess that your proposal can improve the usual school practices, especially for the disability you take into account?

The prospective support teachers were suggested to start from their classroom stage experience and to present their work by using a series of comics (made with Toondoo) in a PowerPoint file.

Analysis of workshop's outcomes

Prospective support teachers have been engaged in a workshop session, where they were requested to create a digital storytelling, according to some given guidelines, working in groups (see previous section).

In the following, we are going to analyze the outcomes, using the previously presented C&D model (see Figure 1 in section 2), in order to recognize if the designed digital storytelling actually consist in a striped problem.

It is important to note that all the teachers claimed that they took into account students with disabilities, actually known in their stages.

Let us see the stories. The subsections' titles are the same of the stories' ones chosen by the teachers.

Cultivating mathematics

The setting

The group was composed of 5 teachers, teaching different subjects: English language (one person in the group), Italian language (one), Technology (one) and Geography (two).

They take into account a 15 years old pupil M, that is Lorenzo, having a medium mental disorder, living with her parents and a younger sister and attending the first class of an Agricultural Technical Institute. lives. Even if he lives in a city, he has a very strong bond with the countryside where his grandparents live. Concerning the logical-mathematical area, Lorenzo knows the natural numbers and he is able to perform simple calculations with the four operations, whilst he needs the calculator to perform more complex operations. He can recognize geometric figures in the real world as well as the related concept of perimeter and area. He is able to use the telephone, the mobile phone and the computer autonomously.

The story

Lorenzo is 15 years old and this year he decided to accept the proposal of mum and dad: to spend a month at his grandfather Gino's home in the countryside. He will have a goal to reach: to become a good farmer just like his grandfather. If he will succeed, he will have a sum of money: 100 euros to be spent as he wishes!!! Lorenzo really likes to help his grandfather: to give food to animals, to go with him on the tractor, pick vegetables in the garden. Grandpa Gino, who likes to make jokes and riddles all the day, is really excited to finally spend some time with him. This year Lorenzo received from his grandfather an important task ... he will have to take care of his own vegetable garden, following his grandfather's advice. Grandfather Gino: "I entrust you with an important task, this year you will have a vegetable garden all of your own. I will give you a piece of land like a geometric figure, but you

will have to understand which geometrical figure is”. It would be easy if grandpa Gino was not a great prankster. Grandfather Gino tells Lorenzo: “You will have a prize if you follow my instructions. Starting from the road counts ten meters going towards the house, then put a stake and go down for more 5 meters going to the stable”. Grandfather Gino begins to observe his nephew, who is a little surprised and starts to think. To recognize the terrain, Lorenzo must follow his grandfather's instructions (he was equipped with the map in Figure 2). Lorenzo: “Then I start from the street, I imagine walking for 10 meters towards the house ... I put a nice stake (to remind me of the point) and go down more 5 meters towards the stable ... I put another stake and go back more meters”.

Figure 2: The map in the “Cultivate Mathematics” story

Lorenzo finally identified the land his grandfather gave him ... but another problem arose ... How many plants can he plant? Lorenzo asks his grandfather how much space is needed for a tomato plant in order to grow well. Grandfather Gino answers: “Who knows ... I do not know ... I would say 1 meter by 1 meter” (Figure 3).

Figure 3: One of the comics of the “Cultivate Mathematics” story

Lorenzo, not convinced of the answer, decides to do his calculations starting from his grandfather's instructions. (Note: here M is required to solving the posed problem).

Calculating ... calculating ... Lorenzo discovers as a good farmer how many seedlings he needs. Grandpa immediately starts again with another one of his riddles. Grandfather Gino: “We have to go to the market and we can use only 50 euros Will we be able to buy all our plants?”. At the market, Lorenzo discovers that each pack of eight plants costs 3 euros. Lorenzo: “we have to go and only 50 euros can we use ... will we go out and buy all our plants? Are 50 euros enough?”. Lorenzo, satisfied with his work, goes quietly and safely to the market. He is no longer afraid of mathematics because he has managed to solve his grandfather’s riddles.

The following Table 1 shows the analysis of the above story-problem according to the C & D model.

Table 1: C&D analysis of the story-problem “Cultivate mathematics”

STEP	YES/NO	ANALYSIS
C1	YES	There is an character, Lorenzo, who had the aim of becoming a good farmer like his grandfather Gino. This goal can be reached following various Gino’s guidelines.
D	YES	Gino’s guidelines require Lorenzo to solve various problems (to recognize a terrain to cultivate, to decide how many plants the terrain can contain and if 50 euros are enough to buy them). . The solutions to those problems allow Lorenzo to reach his goal. This purpose is probably the same as M, who attends an Agricultural Technical Institute, and he is very close to his grandparents.
C2	YES	Lorenzo’s goal has not yet been achieved.
C3	YES	The story presents several mathematical problems: recognizing the <i>geometric</i> shape of the land, calculating the number of plants that can be planted, calculating the cost of the plants. All the problems are Lorenzo’s problems.
C4	YES	The parts of the story are related to each other from a narrative point of view through chronological links (<i>but now there is another problem, Grandpa immediately starts again with one of his riddles</i>) and causal (<i>to recognize the terrain, Lorenzo must follow his grandfather’s instructions</i>).
C5	YES	The information and details make sense in the narrative context because they help Lorenzo to solve the questions posed by his grandfather Gino.

In the text there are no narrative fractures and there is a link between question and context. The context is well structured from a narrative point of view and thus it can be classified as a striped problem.

The mathematical problems arise along the story, which does not provide answers to the questions, but it is delivered with suitable schedule in order to allow the student M to reflect and to solve before going on. However, some remarks on the mathematical correctness of the proposed questions are needed.

Let us consider the first question, concerning the recognition of the geometric shape of the garden, the story gives information on the boundaries of the land (...*starting from the road counts ten meters going towards the house, then put a stake and go down for another 5 meters going to the stable...*), referring to figure 2 that is delivered to the student M. Note that the figure lacks any unit of measurement and therefore the student could trace different terrains of different shapes.

In fact, in the second question (How many plants can he plant?), the student has to calculate how many plants can be planted in the vegetable garden, knowing that each plant occupies one square meter. The resolution of this question, however, is closely linked to the constructed figure, because the student must take into account both the shape of the vegetable garden and that of plants (Figure 4).

Figure 4: The shape of the plant in the story “Cultivating mathematics”

From figure 4, one can infer that one plant needs one square meter of terrain. If the terrain has a rectangular shape of n square meters, then just n plants can be planted. But what happens if the terrain has a triangular shape with the same area? Maybe near the vertices, there is not enough space to plant. This suggests that the given problem needs an a priori in-depth analysis, which seems not envisaged by the teachers. We can suppose that the teachers assume implicitly that the shape of the vegetable garden is rectangular.

The third question (*we have to go to the market and only 50 euros we can use Will we be able to buy all our plants?*) requires the student M to divide the number of plants by 8 as each package is 8 plants, but at the same time to take into account the realistic constraints given by the story, which means to approximate the result by excess, so as to understand how many packages are needed (for example, if the result of the division is 3.2, then he needs 4 packs), then to multiply the number of packs for the cost of each pack (3 euros) and compare this cost with the 50 euros available to see if they will be enough to Lorenzo.

The secret passage

The setting

The activity is carried out by a group of 4 teachers, teaching the following matters: French and Spanish, English, Mathematics-Physics and Mechanics - Technology. They conceived this activity is framed in a view of inclusive didactics (as they declare). The classmates are grouped four by four, and each member of the group is expected to solve a problem by exchanging views each other. The solution should come from an agreement among all the mates in the group.

M attends the first class of the Artistic High School. She is a student with Down syndrome with a medium mental retardation. She has difficulty in memorizing concepts and in generalizing the application of these concepts in various fields, in the comprehension of the text and declination of simple problems, in the resolution of simple logical problems. She is bored listening to the teacher's lessons and performing computational exercises. She loves videogames, especially those with steeplechases, pirates and fantastic characters.

The story

On a spring afternoon four friends, Samuel, Francesco, Namir and Simona, meet at Samuel's home to play computer games. While Samuel and Francesco play, Namir and Simona look themselves in the mirror trying some T-shirts they bought the day before. Namir notes a strange light on the mirror. He moves close and, touching the mirror, he disappears. Called back by the shouts of Simona, Samuel and Francesco turn and move close... "What happened? What happened?". "Namir ... Namir ... she moved close the mirror and I did not see her anymore". Francesco moves close the mirror and touches it with his hand, which disappears as if immersed in a river ... he immediately pulled back it and, turning to his friends, says: "I understood everything! This is a Secret Passage. We have to save our friend. Let us do this, let us take a rope, I tie myself and go in to look for her while you hold the other end of the rope". "Ok". "Ok". And so Francesco slowly disappears in the mirror ... Samuel holds the rope in front of Simona ... slowly the rope begins to flow ... "Simona resist! ... I cannot do it, it's pulling". "Do not leave, remember the words of Francesco". "Simonaaaaaaaaa". In a moment, there is no one in front of the mirror. Will our friends be able to go home? Our heroes meet a pirate who explains what they should do to get home. The pirate gives them some items telling them that they will be useful during the journey: a magic wand and a meter. First obstacle: to cross the river by the available means (Figure 5).

Figure 5: The first question in the "The secret passage" story

After the first obstacle, our heroes arrive at a castle guarded by a dragon. The room has the shape of a square of side 10 m.

You have 4 square-shaped blankets, with a 7-meter long side, and 4 rectangular-shaped blankets with sides 3 meters and 7 meters long. You are required to cover the floor of the room with the blankets without overlapping them to extinguish the fire (Figure 6).

Figure 6: The second question in the “The secret passage” story

Big guys! We have extinguished the fire ... Look there! There is a ladder! Let us climb. We should find the key to open the casket (Figure 7).

Then they went back home.

Figure 7: Last question of the “The secret passage” story

Table 2 shows the analysis of the “The secret passage” problem-story, according to the C&D model.

Table 2: Analysis of the “The secret passage” story-problem according to the C&D model

STEP	YES/NO	ANALYSIS
C1	YES	There are more than one animated character: the four friends Samuel, Francesco, Namir and Simona. They have a goal: to save themselves from a magic mirror and to come back home safely.
D	YES	Solving the questions proposed by the story help the characters to reach their goal.
C2	YES	The goal has not yet been achieved. To achieve it the protagonists need to overcome the obstacles they will encounter.
C3	YES	The story presents 3 different questions (cross the river with the means available, cover the room with blankets to extinguish the fire, find the key to open the casket). They arise from the story as obstacles encountered by the characters.
C4	YES	The parts of the story are related to each other from a narrative point of view through chronological links (<i>After the first obstacle, our heroes arrive at a castle guarded by a dragon.</i>) and causal links (<i>Our heroes meet a pirate who explains what they have to do to get home</i>).
C5	YES	Information and details make sense in the narrative context but not all of them are useful for the protagonists to come back home. However, they aim to engage the students, especially M, who love <i>video games, especially those with obstacle courses, pirates and fantastic characters</i> .

As already seen in the previous story-problem, no answers are provided. It is organized in such a way so to leave the group of students, and in particular the student M, time to reflect and respond. Moreover, the analysis in Table 2 seems to confirm that it is a striped problem. It is worthwhile to note that the course participants tried to closely link the narrative to M’s preferences and attitudes in order to engage him in solving the questions. Anyway, they designed the story-problem in an inclusive education view, addressing a group of 4 students (including M), but no indications can be found in the design which can guide the interactions among the students, and in particular with M, in order to solve the questions. Certainly, it is worthwhile to note the time available for the planning of the story was not sufficient for the participants to consider, in detail, also collaborative aspects.

The design foresees to manage the actions to be taken by the various students. In particular, M is in charge of solving the questions not purely mathematical, that is *to cross the river with the available means and find the key to open the casket*. The first one requires a totally fantastic solution. We can suppose that M will choose to use the magic wand to bring up some bridges or rocks so you can easily cross the river. The second question requires the student to pay attention to the vignette (Figure 7), in order to recognize the shape and the colour of the key depicted on the casket, to understand which key to choose in order to open it.

Moreover, the design foresees a collaborative solving process, involving all the students, for the request to cover the room with blankets to extinguish the fire, as it is more complex and requires a more in-depth analysis.

Let us focus on the last question: to cover a square room with 10 meters side, by means of 4 square blankets with side of 7 meters and 4 rectangular blankets with sides of 3 and 7 meters (Figure 6), without overlapping the blankets. It seems that the question can not be solved without overlapping the blankets. Figure 8 shows two possible configurations. Both of them displays a white region that cannot be covered with the available blankets with no overlapping.

Figure 8: Representation of the mathematical question in the story “The secret passage”

Further configurations can be envisaged but no one of them allows any overlapping of the available blankets. The question, as it is posed in the context of story, should have a solution (*Big guys! We have extinguished the fire*). And in fact, it can have: for instance, cutting the remaining blankets according to the needs. But if we do not exploit the power of the narrative, and so we look at the question in Figure 6 just as a mathematical question, we conclude that there is no solution. Thus this story-problem is very interesting because it pose question that can be solved or not according to the engagement in the narrative or in the mathematical task! This can be positive or not, depending on the teachers’ expectations. If the teachers aim to propose just a mathematical task, then we are in front of teachers who failed in constructing this story-problem, as the participants were very concerned with the story and motivation of the student M, but they neglected the mathematics. This is particularly relevant because in the group there was a Math teacher.

Will I play as a goalkeeper?

The setting

The activity is carried out by a group of 4 teachers, composed by a Math teacher, a French teacher, an English teacher and a Motor Sciences teacher.

The student M is fourteen years old and she attends the first class of an Economic Technical Institute. She loves sport and in particular football: she attends, in fact, a football school in her city. She has mild intellectual disability in comorbidity with more behavioral and emotional disorders. Concerning the logical-mathematical area she works sufficiently with the four operations but she has more difficulties in problem solving.

The story

Marco has a passion for football and he absolutely wants to play in the decisive game on Sunday, in the role of goalkeeper. His great passion pushes him to wonder how much probability he will have to play as a goalkeeper, as it depends on the fate. The story consists of a dialogue between father and

son which, by means of various stimulus questions, allows Marco to understand some key concepts in probability, but also to predict the possible outcome of his problem (only by the extraction of a card) . Marco: “Mister, who of us will be the goalkeeper in the Sunday game?”. Mister: “You both are fit... so it will depend on the fate. Who will extract the highest card from a deck will be the goalkeeper” (Figure 9).

Figure 9: The first dialogue of the story “Will I play as a goalkeeper?”

Marco comes back home and tells everything to his father. Marco: “Daddy, how many chances do I have to play on Sunday as a goalkeeper?”. The father: “Eh ... we need to do some calculations ... we should decide who extracts the card as first. May we toss?”. Marco: “Mmmh ... yes! So we have the same chance to extract as first!”. “Let’s take a deck of 52 cards ... mmmh ... there’s a problem: how many 5 are there?”. Marco: “There are 4! Mmmh ... and so ... that means we could draw two cards of the same value. So who extract as first?”. The father: “And if we consider only cards with same seed?”. Marco: “Mmmh ... yes, they are 13 and no value is repeated”. Marco: “If Luca extracts the number 5 from the deck of 13 cards, what is the probability of extracting a higher value?”. The father: “How many numbers greater than 5 are there?”. Marco: “6, 7, 8, 9,10, 11, 12, 13, there are 8 numbers”. The father: “If Luca does not put the 5 back in the deck, how many cards may you choose?”. Marco: “13 minus 1, then 12 cards”. The father: “The probability is given by the favourable cases divided the possible cases, so you would have ...” (Figure 10).

Figure 10: Dialogue between Marco and his father in the story “Will I play as a goalkeeper?”

Marco: “So, the favourable cases are 8, the possible cases are 12 ... the probability is $8/12$ ”. The father: “Exactly, if Luca will extract 8, then your probability of extracting a card with greater value would increase or decrease?”. Marco: “The numbers greater than 8 are 5 ... so I would be less chances”. The father: “Exactly, good”. Marco: “I understood one thing... Hope that Luca will have an ACE !!!”.

Table 3 shows the analysis of the story-problem “Will I play as a goalkeeper?”, according to the C&D model.

Table 3: Analysis of the story-problem “Will I play as a goalkeeper?” according to the C&D model

STEP	YES/NO	ANALYSIS
C1	YES	There is a animated character, Marco, who has the goal to play as goalkeeper in a decisive match on next Sunday.
D	NO	The character goal depends on the extraction of a card from a deck. So there is nothing that Marco can do in order to achieve his goal. Anyway the story shows various questions in order to let Marco to understand how many chances he has to achieve his goal, depending on how the extraction will be done. The story also the solutions to the proposed questions, so that no work is in charge of the student. The story is just used not to introduce and explain a topic, such as probability.
C2	YES	The purpose has not yet been achieved, also at the end of the story. The character is just aware of what chance could have to achieve the goal.
C3	YES	All the questions in the story concerned the actual goal of the character, that is to understand how many chances he has to play on Sunday as a goalkeeper, so they are not artificially introduced.
C4	YES	The parts of the story are related to each other from a narrative point of view through chronological links (<i>Marco come back home and tells everything to his father</i>) and causal links (<i>Daddy, how many chances do I have to play on Sunday as a goalkeeper?</i>). The father: “Eh ... we need to do some calculations ... we

		<i>should decide who extracts the card as first).</i>
C5	YES	The information and details make sense in the context and give meaning to the narrative, engaging the student M, <i>who loves sports and in particular football: he attends, in fact, a football school in his city.</i>

This seems to be a broken problem because step D of the C&D model is not satisfied. It is enough, however, to eliminate the answers to the questions from the story to make it a striped problem. It is interesting to observe how the story ends, that is with the Marco's sentence: "I understood one thing... Hope that Luca will have an ACE!!!". It would be desirable to design the story in order to bring the student M to this conclusion by himself.

From a mathematical point of view, the story is well structured and the dialogue between father and son slowly brings the student to think about concepts of classical probability: favourable cases, possible cases, extractions with and without reintegration.

In designing this story-problem, the participants paid a lot of attention to the mathematical contents, also thanks to the presence within the group of a Math teacher. Even the mathematical content, that is probability, seems to have been chosen carefully, being a topic widely dealt with in an Economic Technical Institute, school attended by M. Note that although the story can stimulate and motivate the student M as it concerns the favourite sport of M, the designed problem consists in a broken problem. In fact, the answer cannot allow the character to achieve her goal, but just to understand what can happen. This can reduce the engagement of the student M, so the narrative could be not so effective as desired.

I'm right!

The setting

The activity is carried out by a group of 4 teachers, composed by a Motor Sciences teacher, a Philosophy teacher and two English teachers.

M is a student with hyperkinetic disorder, attending the first class of a Technical Institute. She has a great passion for football: in fact, she is never bored when she plays football. Football appears in all school disciplines: in the Geography lectures, every state is a football team; during the English lectures, M talks about English footballers; and so on, except for Math lectures, where M cannot find any connection with football, so she gets nervous. Mathematics is her enemy: she has the feeling that the numbers make her spite, also because she believes that all the problems and the exercises should be solved with a single step. If she could see a problem like a football match, with lots of steps and a team work, maybe mathematics would excite more interest.

The story

Domenico and Pasquale are two friends and they are very close each other, they spend whole afternoons together playing the PlayStation. On the football field, however, they play in the two rival teams of the country and they compete heated for the record in the placement. While Pasquale enjoys playing with numbers, for Domenico this is a hostile and distant world. Pasquale would like to share this passion with his friend and he guesses that maybe football could be the right tool to put Domenico in contact with the numbers. It's Saturday afternoon, Pasquale and Domenico are playing animatedly on PlayStation, challenging a football game. At a certain point, Pasquale was able to score, starting from a penalty kick. Exulting for the goal, Pasquale says to his friend: "Tomorrow I will repeat the same performance. We will win the game ... indeed, the whole championship!" (Figure 11).

Figure 11: One of the comics of the story "I'm right!"

"What are you talking about?" - replies Domenico - "The championship is ours! We are the strongest ones! We will win. We have lost some battles, but we will win the war.". The two boys, in fact, eagerly await the end of the regional championship to determine which of the two teams in the country (the first and the second in the placement) will be the winner. Taking into account that the Pasquale's team is first in the placement, having one point more than the Domenico's team,, Pasquale replies: "But are you able to do sum? We are ahead ... it's easy to understand that our chance of winning is higher than yours!". Domenico replies: "Look, we're not out of the game yet! Get ready for your defeat!". Pasquale replies: "I'm right! We have 54 points and you 53: if we win, we get 3 points; if we tie, we get 1 point; if we lose, we get 0 points. Do not get tired doing the calculations: we will definitely win!". Domenico: "We have the same chance of winning. Stop with these insinuations without foundation". Pasquale: "How without foundation ???!!! Would you like a little drawing? Look what could happen tomorrow ..." (Figure 12).

I ipotesi: P vince - D perde	II ipotesi: P pareggia - D perde	III ipotesi: P perde- D perde	IV ipotesi: P vince - D pareggia	V ipotesi: P pareggia - D pareggia
57			57	
	55			55
		54	54	
				54
	53	53		
P	D	P	D	P
VI ipotesi: P perde- D pareggia	VII ipotesi: P vince - D vince	VIII ipotesi: P pareggia - D vince	IX ipotesi: P perde- D vince	
	57			
		56	56	
54		55		
			54	
P	D	P	D	

Figure 12: Possible cases in the story "I'm right!" P: Pasquale, D: Domenico

Domenico, discouraged, says: “What confusion! How many combinations! I can understand nothing!”. “Do not worry! The combinations are 9. I try to make a scheme that summarizes them all! You have just to count how many times, among the 9 chances, your team could take the lead and win the championship!” (Figure 13).

Figure 13: Summary table in the story "I'm right!"

“How many times do you have the chance to win? And I? We could even achieve the same result and should go to the play-off!” Pasquale: “So, have you found the three fractions? Now we can also calculate the percentage of victory of the championship, that is how much is the chance to win for each of our teams. Calculate the other percentages and determine who of us is right ...” (Figure 14).

Figure 14: Last slide of the story “I’m right!”

Table 4 shows the analysis of the story-problem “I’m right!” according to the C&D model.

Table 4: Analysis of the story-problem “I’m right!” according to the C & D model

STEP	YES/NO	ANALYSIS
C1	YES	There is more than one animated character. Domenico and Pasquale, who has the goal to win the championship..
D	YES	The problematic goal is to predict which of the two protagonists’ team have more chances to win the championship. In particular, Pasquale tries to convince his friend, Domenico, that his team is disadvantaged. So Domenico’s aims to understand if Pasquale is right. Solving the questions, that is calculating the probability of victory, allows Domenico to predict the winner.
C2	YES	The goal has not yet been achieved. In order to do that, it is needed to calculate the probability of victory of the two teams.
C3	YES	The questions (How many times do you have the chance to win? And I? We could even achieve the same result and should go to the play-off! <i>Now we can also calculate the percentage of victory of the championship, that is how much is the chance to win for each of our teams. Calculate the other percentages and determine who of us is right ...</i>) not artificially introduced but they arise in a natural way along the story.
C4	YES	The parts of the story are related to each other from a narrative point of view through chronological links (<i>Domenico replies ... Pasquale replies ...</i>) and causal links (<i>Do not worry! The combinations are 9. I try to make a scheme that summarizes them all! You have just to count how many times, among the 9 chances, your team could take the lead and win the championship!</i>)
C5	YES	The information and details make sense in the context and give meaning to the narrative, engaging the student M, who <i>has a great passion for football.</i>

The above story-problem seems to be a striped problem, with a good integration between the mathematical and narrative aspects. The story does not provide answers to the questions but explicitly provides some summary information (for example the table in figure 13), aiming at helping the

student M in solving the questions. The participants tried to identify a character of the story, Domenico, with the student M. This can favor the engagement of the student and, therefore, it can foster learning.

The aim of the story is to let the student M think about the concept of classical probability and to calculate some probabilities. The actual goal, however, is to become the student M interested in mathematics, creating a link between mathematics and football. The mathematical problem is well integrated into the story, but it presents some points on which we must pay attention. In Figure 13 the questions for M are the following: *“How many times do you have the chance to win? And I? We could even achieve the same result and we should to go to the play-off!”*. This requires to calculate the number of cases favorable to the three events (in reality, for the third event, the request is not explicit). In fact, the word “chance” is used, rather than “probability”. In Figure 14, Pasquale requires: *“So, have you found the three fractions?”*. The term fractions certainly refers to the concept of probability, i.e. the relationship between favorable cases and possible cases. The teachers seem to have no clear ideas on the difference between the two concepts of possibility (possible cases) and probability. This is even more evident with the subsequent request: *“Now we can also calculate the percentage of victory of the championship, that is how much is the chance to win for each of our teams. Calculate the other percentages and determine who of us is right ...”*, in Figure 14. The request is to calculate the percentages, i.e. to transform the probabilities (fractions), as a percentage, but, always in the same sentence, the term chance appears. Moreover, to answer the questions, it is assumed that M already knows the definition of classical probability and how to convert a decimal number in percentage. This can be difficult to imagine for the student M, who attends the first year, for which mathematics is an enemy, but it is not to be excluded because the probability and the percentages are topics discussed in the middle school.

Discussion of the questionnaire’s answers

In this section we report and discuss the questionnaire’s answers aimed to investigate which are the beliefs of the teachers with respect to effectiveness of proposed methodology for students with learning difficulties or disabilities.

The following table reports the answers given by the various groups of teachers to the first question submitted:

- Why do you guess your proposal is effective for the disability at stake?

Table 5: Answers given by the various groups of teachers to the first question submitted

Group #	Answers
1	The activity carried out is effective in the specific case of disability because, starting from a situation close to the experience and interests of the student M, can stimulate not only the curiosity towards the discipline, but above all to allow him to use all the skills acquired going beyond the application of the mathematical calculation.
2	Digital storytelling can help the student to transform content into skills, through the use of simple language and images close to her world and interests.
3	The designed product allows the student M, through the stimulus questions, to include not only the procedure to calculate the probability of an event, but also to predict the outcome of an event. Through the proposed story, the mathematical problem is contextualized and linked to the specific area of interest of the student in order to stimulate to solve it.
4	The work contextualizes the mathematical content in real situations. The product is effective for the student M because it links mathematics, which is usually in troubles with, to one of her passions, showing that mathematics can be seen as a game.

The above answers show that the teachers ascribe the effectiveness of their proposals to the possibility of engaging the student M. In fact, all of them have designed stories taking into account the preferences and attitudes of M and it is simplified by means of the use of comics with simple language and images. So the teachers assumes that this can motivate the student in becoming interested in mathematics and stimulate him in carrying out the activity.

We should note that the focus on motivational aspects can have some drawbacks. In fact, most of the times it has brought to neglect mathematical contents and correctness of the problems submitted to the students. Moreover, in one case (group 3) the teachers seem to consider engagement as passive identification with the story's character without being actively involved. In fact the story already presents the solutions, cannot engaged the students in trying to solve the problem. Even the final prediction of M, "Hope that Luca will have an ACE !!!", actually prevents the students from making a prediction.

We also note that almost all the teachers point out that their proposal allow a shift from contents/computations to skills.

The following table 6 shows the answers to the second question submitted to the teachers:

- Why do you guess that your proposal can improve the usual school practices, especially for the disability you take into account?

Table 6: Answers given by the various groups of teachers to the second question submitted

Group #	Answers
1	The product is customizable, but also multidisciplinary (involving disciplines such as mathematics, information technology, plant productions, etc.). It is multimedia and appealing.
2	It can be used in inclusive methodologies, it allows the start up of different learning channels. The technique is appealing.
3	Digital storytelling is more effective than usual teaching practices because the narrative, supported by multimedia elements, fosters the learning process as it actively engages the student, with consequent reinforcement of the motivation and of the commitment.
4	The product created can give added value to traditional education because it makes the student the protagonist of her learning.

We note that any of given answers make reference to the specific disability taken into account for the design. So it seems that the teachers consider their products innovative and appealing with respect to any usual student. The innovation has been identified mainly in the use of multimedia and in the power of engagement. The only reference to inclusive teaching refers to the start up of different learning channels, no more specified.

Conclusions and future perspectives

In this work we presented a training experience for teachers in the Special Education Laboratory course: codes of the logical and mathematical language, carried out at the University of Molise as part of a specialization course for teachers who aspire to become support teachers.

The prospective support teachers involved in the course have been able to exploit new methodologies (e.g. digital storytelling) and tools (e.g. Tondoo) in order to design digital story-problems, aimed to engaged students with special needs in mathematical activities.

The teachers have worked in groups, not necessarily including a mathematics expert. The heterogeneity have brought to very engaging stories, which in most of the cases fit the C&D model of striped problems, where the narrative is well structured and the questions naturally arise from the narrative. Anyway, when the problem is not a striped one, it can be slightly modified in order to become so.

It is worthwhile to note that three of the four teachers' workgroups had some troubles in posing correct mathematical questions. This has been true also when a math teacher is in the workgroup. It seems that the attention payed to the story have lead to lose sight of mathematics. So the presence of a domain expert obviously does not guarantee correctness.

The richness of the narratives produced by the prospective support teachers as well as the questionnaire answers seem to reveal an engagement of the teachers in designing digital story-

problems and the belief that such methodology is appealing for students. They are confident that such kind of problems are able to act on the students' affective level of learning, concerning especially motivation and engagement. In fact, all of them have taken into account the student M in her preferences, habits, living context, passions and so on, with the aim of engaging her in solving the posed problems. Anyway, it is evident that they have neglected the mathematical content at stake, posing questions well integrated in the story but not mathematically correct. In one case, they use storytelling in its original meaning, excluding active engagement of the student (in fact they give the solutions, too, to the posed questions).

Analyzing and discussing the products with the teachers can make evident to them that designing mathematical tasks, in particular digital storytelling in mathematics, requires to integrate various aspects. The design needs to take into account not only the affective level of learning, which is important with no doubt, but also the cognitive and meta-cognitive levels. The above analysis shows that all the teachers focused on the motivational factors. Many of them lose the cognitive level (what about the mathematical content - definitions, properties, theorems - we wish the student learns? what she already knows?). Almost all of them lack the metacognitive level: only the story Will I play as a goalkeeper? concludes with something that refers to a control process on learning, but unfortunately it is just telling and it does not foresee to come from the student actually engaged.

From the above considerations, we plan to equip the teachers with problems already well-posed from the mathematical point of view, so to focus only on the narrative.

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