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A computer-based collaboration script to mediate verbal argumentation in mathematics

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This paper reports on a pilot study concerning a first implementation of a collaboration script, aiming at developing students' argumentative competences in mathematics, as part of an interactive digital storytelling. We discuss the outcomes of the transcripts' analysis, which seem to show that the collaboration script fosters the introduction of the student to the construction of arguments as cohesive texts, independently on the student's skill in mathematics, and that the success of the script depends on the learners' engagement in the story and on the team mood.

Keywords: Collaboration script, linguistic, argumentation, mathematics education, e-learning.

Introduction

This paper focuses on a part a wider research (Dello Iacono, 2015; Albano, Dello Iacono, Mariotti, 2016; Albano, Dello Iacono, Fiorentino, 2016), aimed to investigate the effectiveness of the design and implementation of a Digital Interactive Storytelling in Mathematics (DIST-M), that is a platform model organizing mathematical learning activities based on social virtual interactions. The DIST-M consists in collaboration scripts implementing a work methodology for the students that, according to Vygotskian perspective, is expected to mediate specific mathematical competences. A collaboration script is a scheme that regulates and structures roles and interaction in a collaborative setting (King, 2007). The choice of the use of storytelling is related not only to motivational aspects and cognitive effectiveness, but also to the possibility of integrating narrative and logical-scientific thought (Zan, 2011). In our DIST-M the student does not create the story, but she interacts with it. In “Programma Discovery” the student assumes the role of a scientist at NASA, member of a team led by Professor Garcia (head of story and voice platform). The goal of the team is to analyse the data coming from a probe launched on a new planet, trying to figure out if this can accommodate life. During the fruition of the story, the student will face problems, whose solution is needed to continue the work of the team. This paper reports on a pilot study concerning an implementation of the DIST-M focusing on the development of students' communication competences in expressing argumentative mathematical sentences, as they can be considered as critical to the advance of mathematical thinking (Ferrari, 2004). The goal is to introduce the student to the construction of arguments written according to a register shared in the mathematical scientific community. We analyse, from a qualitative point of view, the arguments produced by the students under a linguistic perspective, focusing on the organization of the verbal texts, as cohesive texts, which means words and sentences perceived as a whole entity. We also look at the functioning of the collaboration script in terms of the team work and its impact on the success of the activity. We expect that the collaboration script in organizing the roles and actions within the team fosters the production of arguments and counter-arguments, allowing each member to interiorize the so-born practice.

Theoretical framework

Collaboration script

In cognitive psychology, the internal memory structure corresponding to a sequence of actions that define a well-known situation is named script (Schank and Abelson, 1977). Here each actor has specified roles and actions to take. The script is activated every time the individual is in the same situation. In educational context such constructs differ mainly because of its external definition and they aim to regulate roles and actions of students in collaborative/cooperative learning in order to succeed in learning (King, 2007). The use of external scripts has been incremented in computer-supported environment, where the need of pre-structuring and regulating the social and cognitive processes is much more evident. Concerning argumentation, it is well known that the simple request of collaborating does not guarantee the development of argumentative competences. This can be fostered by means of computer-based scripted collaboration (Weinberger et al., 2007), taking advantages on the use of text-based interfaces that allow the students to have more time to read their written argumentations and their peers' ones and to come back to their writings every time they want. According to Vygotsky (1930), "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (inter-psychological) and then inside the child (intra-psychological)". Although the scripts are externally designed and imposed to the learners, the goal is that they are internalised along the time through the social practice. Only when the external script is interiorised, then it is successful; otherwise we have once again a repetition of actions externally imposed and learned by heart.

Language and cohesion

As the defined script aims to the construction of arguments, we are interested in how the student can propose verbal arguments to support the solution to a given question, apart from the correctness of the solution. Although some theoretical models regard arguments with no reference to language, as a matter of fact, a written argument is, first of all, a written text, and for the student, the tasks of producing a correct text and an acceptable explanation are closely intertwined. This is why we will use a linguistic perspective with related specific tools such as cohesion. This latter allows creating the texture, which is the quality of being a text instead of a disorganised set of words and sentences (Halliday and Hasan, 1976). Though related, cohesion is different from coherence. The first one refers to the linguistic devices needed to realize the second one, which is instead a mental process, proper of the individuals involved in the discourse. The production of an acceptable argument can be hindered by the lack of either mathematical or linguistic competence. Often students produce written explanations that are plain descriptions of the procedures they have carried out, by means of a set of more or less disconnected clauses where cohesion is marked just by the fact that the text they produce is semantically congruent to the actions they have performed. In other words, their cohesion markers are extra-linguistic, and we cannot tell whether or not the writer is aware of the semantical links among the clauses. We believe that the construction of cohesive texts is the first step towards the development of logically acceptable arguments. The script has been designed with the aim of fostering the student to construct cohesive arguments, which can be interpreted by their pairs, independently on their mathematical abilities.

DIST-M script

The DIST-M script presented here aims to allow the student to grasp a method of construction of mathematical arguments expressed verbally. The student is involved in tasks alternately individual and social. Social tasks are realized by means of chat and group forum (Figure 1).

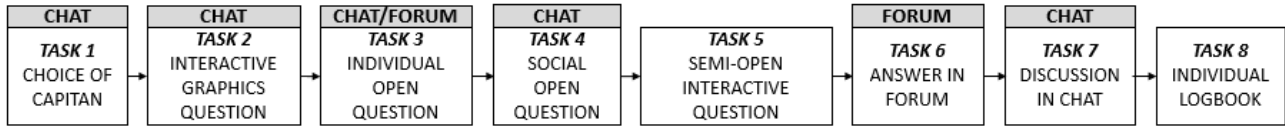


Figure 1: Design of the script

The chat supports the explicit comparison and it mediates (Bartolini Bussi & Mariotti, 2008) a modality of communal acting (to get an answer, an argument that supports its correctness, a reply adapting to the possible contradictory) that from social activity becomes an own way of working of the student. The forum, through its rules of use, supports the sharing and discussion, and in this way, it mediates the interaction inducing everyone to give their own contribution and to listen the one of others. In the forum, each student writes a description of his/her solution, reads / interprets the writings of others and can / must compare his/her texts with those of others. All this requires significant semiotic processes that besides being expected to foster the development of mathematical meanings, are expected to promote social argumentation experiences that might be internalized and become own internal process of each student. Thus, according to Vygotsky (1930), there is a development of “higher mental functions”. In our case we refer to experiences of argued debate on manner of thinking / solving / answering the question, thus with higher mental functions we refer to argumentative skills, concerning the need to support the correctness of their answers with relevant topics, socially and mathematically acceptable. The functioning of the DIST-M requires different types of interactions: interaction with the script and interaction between the members of the team. The goal is to give a shared solution for the task, but the main achievement for the single student is to formulate his/her own argument (as a text) supporting the correctness of such a solution. In the script specific constrains have been designed to induce the production of personal arguments, their comparison and eventually the elaboration of a final answer, mediating the moving from an informal to a formal expression of the final individual answer.

In the following, we give a brief description of the various tasks constituting the script (Figure 1). At first the group chooses its own Captain talking to group friends in the group chat (Task 1). He is in charge of engaging all the team members in following the tasks of the script. The next task is the interaction with a GeoGebra interactive construction (Task 2). The aim is to investigate and solve a problem posed by the story. After a more purely experiential phase and subsequent guided reflection, the student answers on the forum to an open question aimed to generalize the experience and the results to which the student has come (Task 3). When all students have submitted the response to the Forum, the discussion continues chatting with the aim of achieving a common response that the captain reports on the chat (Task 4). In the next task, the student responds individually to a semi-open interactive question (Task 5). The interaction consists in manipulating the words-blocks available to build the response and motivation to the previous individual and group question, and in receiving a feedback on the correctness. The words-blocks have been constructed using some answers collected in a pilot. In order to highlight the causal structure of an

argument, the causal conjunctions, which are responsible of the cohesion, constitute separate words-blocks from the other ones. Then the student is required to report on the forum the phrase built by words-blocks with the received feedback and he can see the ones by his peers (Task 6). It follows a chat group discussion to reflect on the words-blocks sentences proposed by all the members with the aim of clarifying the correct answer and argument (Task 7). Finally, the student writes in the personal Log Book all information considered useful for the mission, the impressions on the activity, the difficulties encountered and how they were overcome (Task 8).

Experimentation

The prototype used for the experimentation has been realized by means of open-source or free tools, that have allowed to create new interactive graphical applications and semi-open interactive applications (Dello Iacono, 2015). The pilot study has involved 23 10th grade students of Liceo Scientifico in Pompei (NA, Italy). The students have been split into 6 teams, each of them constituted of 4 students, except one constituted of 3. The teams have been randomly assembled, so that each student at the beginning did not know his/her team mates. Students belonging to the same team could communicate only through the forum and the chat. In the following, we analyse and discuss the experiment with respect to the following key points: (i) the production of verbal arguments for supporting of the solution to a question; (ii) evidence of the different functioning of the script (that is the implementation of the designed learning activity) according to the student's engagement with respect to the story and the team work.

Concerning the first point, we analyse, from a qualitative point of view, the arguments produced during the individual open question and the answer in forum (Task 3 and 6 in Figure 1), that is before and after the semi-open interactive question, in order to investigate the effectiveness of the script. The students are required to answer if and why, fixed a sector in an aerogram, the angle varies according to the radius variation. As we will see in the following, the comparison between the nature of the individual arguments produced during the two tasks shows evidence of an improvement in the cohesion of the explanations constructed. In order to verify the cohesion, we look for the following cohesion markers in the texts produced by the students: lexical repetition (consisting in repetition of words), grammatical repetition (reference, that indicates something already appeared in the text, and ellipsis, that consists in the deliberate omission of words that are required to make up the sense), conjunction which allows to link two parts of a discourse (external, when it refers to a fact, internal, when it refers exclusively to the organization of the text).

Let us consider the team 2. At Task 3 only 1 student provides an argument explaining his/her answer, and he/she is the one who draws team's attention on this request, actually, replying to a mate enquiring of the platform's feedback on his/her answer, he/she says in chat:

1 S7 me too, but we are required to justify our answer

So next his/her answer in the forum is the following:

2	The quantity to be represented is equivalent to 20%.	A first reformulation of the data of the problem
3	$360^\circ:100\%=x:20\%$	S7 carries out a calculation
4	$x=(360 \times 20):100=72^\circ$	

5	Although the radius changes, the size of the angle does not change	A conclusion is drawn on the previous calculation.
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What is posted in the forum is mostly like a report of his reasoning (thinking aloud) without any cohesion marker. It can be seen as a report the mental process in the mind of the writer S7 and in his view it is coherent. This may not be the case for a reader, as it was for another student who asked for clarification. So S7, in order to explain to him, transformed such a personal reasoning in a new text.

6	The angle of the coloured part does not change varying the radius	The conclusion becomes the first statement expressing the answer to give.
7	Because in a circle the angle is always 360° and then 20% is always 72°	The previous calculation has been interpreted to become an explanation of answer.

The new text is cohesive. As a matter of fact we note lexical repetition (angle), external conjunctions (because, then), ellipsis (20% refers to 360°). The difference between the two texts consists in the fact that the cohesion of the text can help the reader to grasp its coherence, which may remain inaccessible for the first text. An effective use of cohesion promoted the shift from a personal report of reasoning to an argument: the sequence statement – calculations – conclusion became a statement plus an explaining argument. Such a cohesive text was generated for communication goals: the request of sharing his/her personal answer seems to have induced the student to better articulate the solution process transforming the calculations into a verbal text providing the reason of such calculation. So the collaborative script has promoted the construction of cohesive argumentations, because of the need of improving communication within the group.

In Task 6, we note a clear improvement: 4 students (that is all members of the team) produce an answer that includes an argumentation. In particular, 2 students (S5 and S8) who did not justify in Task 3, when reporting the answer made of words-blocks, not only produce a justification, but both of them go further the request and rephrase with their own words the arguments.

At Task 3, S8 writes the non-cohesive sentence (there is only an internal conjunction “anyway”):

8 S8 Varying the radius anyway the angle does not change

Then, at Task 6, he writes:

9	The angle does not vary because it is always equal to 20% of the circle angle.	External conjunction (“because”), reference (“it”).
10	The other scientists completely agree with me as varying the radius there is only an extension of it and the angle remains unchanged.	External conjunction (“as”), reference (“it”), lexical repetition (“angle”).

The first sentence is the one constructed by the words-blocks, as required in the Task. Then the student get back in touch with the story and he/she seems engaged and making reference to the scientists, he/she explains in his/her words why all the scientists agree and produces his/her own arguments for supporting the given answer. The second sentence is cohesive. Also in this case the script, requiring reporting the answer constructed by words-blocks and the scientists’ feedback, seems to promote the construction of arguments in terms of cohesive texts.

A similar evolution is shown by student S5. At Task 3, she produces a non cohesive text with no markers of cohesion:

11 S5 The angle does not change, only the radii vary

In following tasks, he/she writes:

12	The angle does not change because it is always equal to 20% of the circle angle.	External conjunction (“because”), reference (“it”).
13	All the members of my team has the same idea. I have the angle is always the same because in a circumference the angle is always 360°, then 20% of 360° is always the same	Two lexical repetitions (“angle”, “360°”), two external conjunctions (“because” and “then”)

Also the student S5 at beginning reports the answer made by the words-blocks, but later he/she refers to the story and he/she seems so engaged to say “my team”, the team of the scientists to which he/she belongs in the story, and when he/she refers to the story, he/she rephrases with his/her own words the answer and its motivation. The sentence constructed by S5 is cohesive. Thus, it seems that the functioning of the script, based on sharing the answers and impelling to find an agreement might lead to appropriate the meaning of argument as explaining and supporting the correctness of the solution by means of cohesive texts.

Let us consider a case where, even if the answer given by the student is not correct, we can anyway observe a shift towards the production of an argument. The student S22 at Task 3 writes:

14	Greater is the radius as much as the angle decreases.	This text is not cohesive (there is no markers).
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At Task 6 he/she writes:

15	The angle decreases because it is inversely proportional to the radius but the other scientists do not agree	Two external conjunction (“because” and “but”), ellipsis (“the angle” is omitted in the secondary sentence)
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Here we have a cohesive text constructed by means of the words-blocks. Even if the answer is not correct, there has been the production of arguments. So, the script seems to work according our goal (to foster verbal argumentation) independently on the correctness of the mathematical content.

Similar behaviour can be observed in the other teams: we have only 8 students among all teams that produced argumentation at beginning, whilst at the end all of the 23 students do it. In particular, the request of sharing on the chat seems to have a mediating function leading to transform a personal reasoning into a public argument. As shown above, the students do not limit themselves to report the sentences constructed with the words-blocks, but they also reproduce arguments with their own words assembled in a structure similar to the ones suggested by the script.

Concerning the second point, the transcripts show evidence that the effectiveness of the activity is strongly influenced by the students’ engagement with respect to the story and to working in group. The effective work of Team 2 seems to occur because all the members were engaged in the story and shared a good mood allowing collaboration. However, in some other cases, we can see that the

activity fails if this does not occur. Let us consider for instance, team 5. The Task 3 seems to work well, the students are engaged in the activity and produce quite different argumentations:

16	S17	360:100
17		$3.6 \times 20 = 72$
18		varying the radius the angle does not change
19		because the percentage is always the same
20	S20	varying the radius the angle indicating the percentage of the considered
21		stone does not change because 20% of 360° is always 72° , $360.1/5=72$

Arriving at the Task 6, we find that they seem to have lost interest in the activity. Looking at the chat transcripts, there is evidence of a change of the team's mood. Actually, students start to become nervous around the end of Task 4:

22	S20	but we have not yet given the first agreed answer beep
23	S18	WE ARE DISCUSSING NOW TO HAVE AN AGREED ANSWER
24		20, you are a genius of evil, connect you brain

Team mood in chat get worse until the beginning of Task 6:

25	S18	HAVE YOU UNDERSTOOD?!
26		DO IT ALL OF YOU 4 IF YOU DID NOT DO IT YET!
27		I said to you in the session share not in the notes, I was sure that you did it
28		Hurry up to write in the sharing session
29		THERE ARE TWO SESSION OF beep. S20 who are you?

At the Task 6 the students have lost their initial engagement and do not satisfy completely the requests. It seems evident that the mode of operation has been strongly affected by the negative engagement, in particular of the Captain, and by the impossibility of collaborate.

Conclusions and future directions

In this paper we have reported on a pilot study concerning a computer-supported collaboration script, aiming at developing students' verbal argumentative competence. The analysis of the students' transcripts seems to show that the collaboration script fosters the introduction of the student to the construction of arguments as cohesive texts, independently on the student's skill in mathematics. Some students shift from producing computations to constructing cohesive argumentations that make use of the previous calculations; some other students, although they do not get the correct answer from the mathematics point of view, also produce cohesive texts as expression of their reasoning. We are now working on a quantitative data analysis, by means of statistical test, coding cohesion of the written students' productions to compare Task 3 and Task 6, in order to confirm the effectiveness of the script as shown by the transcripts in the previous section. Moreover, in order to check that students really interiorized the script and not only repeat what they did before, as well as the use of the cohesion, we are implementing a new script, as continuation of the story, without the word-blocks. There is also evidence that a negative mood in the work team can compromise the success of the learning activity. To this aim, we are implementing a new version foreseeing the introduction of a role for each member of the team, behind the Captain, avoiding that somebody in the group gives away the responsibility. We are going to prove that the

designed script, suitably modified in order to create a positive mood in the work team, promotes effectively the construction of cohesive texts and the fact that there is a strict interconnection between them and logically acceptable arguments.

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