

AN ONLINE VYGOTSKIAN LEARNING ACTIVITY MODEL IN MATHEMATICS

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This paper describes part of a broader research aimed to investigate the feasibility of using an e-learning platform to implement a Vygotskian educational model for mathematics education, based on mediation and peer interactions. We define a Learning Activity model within a Digital Interactive Storytelling in Mathematics and report how it has been implemented with Moodle. The activity uses both experiential and discursive approaches to mathematics learning and exploits individual and social tasks. We discuss from a qualitative point of view the outcomes of an early experimentation put into practice in order to validate the model and give evidence of some occurrences that suggested us some adjustments to the template.

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1 Introduction

This work is part of a bigger project (Dello Iacono, 2015; Albano *et al.*, 2016) aimed at investigating the possibility of using an e-learning platform to implement a Vygotskian educational model for mathematics education based on mediation and peer interactions (Vygotskij, 1934). In order to trigger students both on the motivational and the affective level (Zan, 2011), we adopted a competence-based approach, immersing students in an engaging story (Inan, 2015; Gould & Schmidt, 2010, Ravanelli, 2012). Therefore, we are working on a Digital Interactive Storytelling in Mathematics (DIST-M) model, where students can play an active role within the story. The activity model uses both experiential and discursive approaches to mathematics learning, integrating individual and social tasks (Kieran *et al.*, 2001, Holman *et al.*, 1997). We focus on peer learning (Boud *et al.*, 1999), that is the use of teaching/learning strategies where learning occurs without the prompt action of a teacher but just due to peer interactions (Falchikov, 2001).

Here we report a DIST-M Learning Activity template about argumentation in mathematics. This paper starts from a first study (Dello Iacono, 2015) and takes into account the a posteriori analysis of some classroom experimentations made with an early prototype concerning a case study about a “Discovery program” where students act as NASA scientists, members of a staff guided by Professor Garcia (role played by the e-learning platform). The *équipe* should analyse some data coming from a probe landed on a new planet to investigate whether it can host life. The mathematical content of the story refers to descriptive statistics.

Finally, we present and discuss a qualitative analysis of the protocols of the early experimentation, made to validate the Learning Activity model. The outcomes of the analysis have been used to refine the model from the methodological and technological point of views.

2 Methodological and technological features

The methodology behind the design of the Learning Activity template is based on a mixed approach, which puts together an experiential approach, where the student can manipulate interactive objects to formulate and test hypothesis, and a discursive approach to mathematics learning, fostering student’s internal debate and discussions among peers while forcing an argumentative approach. The Learning Activity foresees various phases, where students work alternating between individual and social settings and are required to make experience and communicate.

The first design foresaw a group leader, the Captain, democratically chosen

within the group, who was responsible of the involvement of the whole staff in the activity. The first experimentations spotted the need for a role for each group member, so we introduced three new roles, concerning the competencies required for a successful mission (Albano *et al.*, 2016).

The analysis of the experimentations suggested to simplify the interactive mathematical tools to avoid distractions, and to use more informal and easy communication tools, chats instead of forums, to ease communication.

From the technological point of view, our main goal is to simplify the reproducibility of the method by a willing teacher. This is why, in our implementation, we used only free, easy to use and open-source tools, such as: the e-learning platform Moodle, to implement personalised learning paths using the “Lesson” module; Toondoo, a program to easily create comic strips; and GeoGebra, to create dynamic mathematical objects.

In the following we describe two applications exploiting Moodle Lessons and GeoGebra to provide new types of questions with automatic assessment (Dello Iacono, 2015). The first one is the Interactive Graphic Question (IGQ), which consists in a GeoGebra interactive construction that the student is required to manipulate and set to obtain the answer to a given question. The application returns a dynamically generated code, reflecting the status set by the student. This is one of the major changes introduced from the previous version, where only three outcomes were possible: correct, semi-correct and wrong. This allows to collect more information on the manipulation performed by the student and to arrange more personalized paths. The second one is the Interactive Semi-open Question (ISQ), which consists in a question whose answer can be constructed by dragging and dropping word-blocks chosen among a predefined set. This application, implemented with GeoGebra, has a double aim: from the technological viewpoint, it overcomes the difficulty of submitting automatically assessed open-ended questions; from the educational viewpoint, to boost mathematical argumentation, moving from a colloquial verbal register to a more literate one (Ferrari, 2004). The main difference from the previous implementation is that the word-blocks now have been pre-arranged to highlight the causal structure of the argument of the constructed sentences, according to one of the following schemes: answer + causal conjunction + argument or causal conjunction + argument + answer. The application generates a code on the fly, reflecting to the textbox contents. As semantically equivalent sentences exist, there are semantically equivalent codes. This means that many codes correspond to correct sentences, the same is true for semi-correct (correct answer and wrong argument) and wrong sentences. The previous version only allowed one code for each case.

3 The design of the Learning Activity

The Learning Activity aims to foster students' mathematical argumentation, engaging them in individual and social tasks, requiring colloquial and literary linguistic registers at various levels of mathematical thinking. The social phases occur by means of chats and forums. The former support the explicit and synchronous debate among peers, mediating a common way of acting, which is giving an answer with a justifying argument and a reply suitable for possible contradictory opinions, which can move from a social activity to an individual way of working. On the other side, the forum, with the formal setting imposed by its asynchronous nature, supports the formalization, the sharing and the comparison, inducing each student to give his own contribution and listen to the peers. The semiotic processes supported by chat and forum promote social experiences that can be interiorized by the student, allowing the development of "higher mental functions" (Vygotskij, 1934).

Going into design details, we recall that the Learning Activity is part of a story, where the student is actively involved. Students work in four-people groups, strictly interacting with a team of scientists who guide the whole mission.

Phase 1: Choice of the roles

Since each group member should play a role, we devised the following four, according to the leading competences for the activity. The "Science Officer", who is in charge of Math Literacy, i.e. the capability of solving the mathematical questions posed during the story. The "Navigator", who is in charge of Digital Literacy, i.e. the capability of using ICT tools effectively. The "Communications Officer", who is in charge of Blog Literacy, i.e. the capability of summarising the speeches of the mates and formalising them with a social media. The "Captain", who is in charge of Social Literacy, which is the capability of managing the group from a social point of view. He should promote the participation of all the mates in all discussions and decision processes. He is the leader of the group and his role is crucial for the success of the whole activity. Each student can propose himself for a role, the student who self-applies should have a good sense of self-efficacy in the competence addressed by that role or, if the group makes the choice, the group guarantees for the chosen person. All students are required to cooperate and help the other group members.

According to the chosen role, the platform guides the student along a different path of the story where Professor Garcia explains the tasks required and the importance of the role for the success of the mission.

Phase 2: Manipulation and Reflection

Once the roles for each team member has been established, the team starts to work facing the first question posed by the scientists (through the platform) as an IGQ. As already seen, an IGQ requires the student to experiment, manipulate, formulate and test hypotheses before giving back an answer to the scientists. A chat is also available for asking help to mates, if needed. In our case study, the IGQ presents an aerogram, with unitary radius, where the coloured portion, corresponding to an angle of 72° , represents the percentage of red stone found on the new planet (20%). The student is asked to represent the same percentage on another aerogram with a bigger radius, that can be set with a slider to an integer value between 1 and 4. Analogously, the student can move two control points on the circle to change the angle. The resulting code represents both the radius and the angle. The answer will be labelled as semi-correct if the student chooses a wrong radius or a wrong angle (but not both of them).

Upon submission of the answer, according to the three outcomes (correct, semi-correct, wrong), the device submits a personalised open-ended question (that the student is supposed to answer without communicating with peers). The purpose is to verify that has not been randomly chosen.

Phase 3: Individual Open Question

After personal reflection, all students are then required to answer another strictly related open-ended question. In the case study, Professor Garcia asks “In order to ease the task to other scientists with the same problem, it would be useful to take notes on how you addressed and solved the question. Try to explain how the coloured angle varies according to the radius change, arguing your answer”. This phase has been realized with a “Question & Answer” Moodle Forum, that prevents the student to see the others answers before posting his own, avoiding to be influenced by the others. The aim of this phase is to evaluate the efficacy of the previous thinking phase.

Phase 4: Forum discussion

After a mainly individual phase, students are now expected to debate and agree on a common answer, starting from those posted in the previous phase. Using a “Question & Answer” forum “forces” a more literate linguistic register (typical of the written communication) instead of a more colloquial one (typical of the oral communication), implicitly fostered by the chat.

Phase 5: Joint response

Once the team has reached a generic agreement using the forum, the team is asked to agree on the text to submit to the scientist, this step requires a more literate linguistic registers. The Communications Officer is in charge of delivering the agreed answer using an Assignment with Group submission. This tool allows each member to see and modify the answer before confirming the submission. The system requires the agreement of all group members before considering the submission as done. The actual submission is made by the Captain, who also checks that everyone has contributed and agreed with the final version. The Science Officer is in charge of checking the coherence between the agreed answer and the discussion done in the forum, as well as the mathematical correctness.

Phase 6: Interactive semi-open question

Once the team agreed on the answer, each student is asked to reformulate it by means of word-blocks using an ISQ, with the aim of moving towards a more literate linguistic register, as accepted in a scientific community.

The scientists give their feedback to the student and the story continues accordingly. If the student answers correctly, the scientists ask him to help his mates in troubles, implicitly giving the role of “expert” among peers. If the student gives correct answer but fails the argument, the scientists ask the student to post the constructed sentence in the forum to investigate with peers why the given argument was wrong. If the student completely fails the answer, the student is simply guided to the next phase, avoiding to emotionally overloading the student.

Phase 7: Answer and discussion forum

After the scientists’ feedback, a comparison phase occurs. Each member is asked to post his constructed sentence in a Question & Answer Forum, together with the scientists’ feedback, if positive. The “experts” help the mates in trouble explaining the reasoning made to obtain their correct sentence. The ones who failed the sentence or missed the argument can now compare their reasoning with the experts’ ones, who actually mediate the socialized learning in the proximal development zone.

At the end, Professor Garcia starts a new discussion on what has happened, the Captain, who takes care that everyone expresses his opinion and ideas, manages this phase.

Phase 8: General forum

If one of the team misses an “expert”, this means that nobody has obtained the correct sentence and the discussion of the previous phase could be unable recover the gap. In this case, since the Learning Activity has been implemented to let the correct answer arise from individual thinking and social discussions, the team can access a general Experts’ Forum, where each “expert” student should participate to help everyone. This phase is therefore optional and the Experts’ Forum is always active.

Phase 9: Logbook

At the end of the Learning Activity, each team is required to take notes, in a Group Logbook, concerning the scientific results they found during the activity and considered useful to continue the mission. It is implemented using a Moodle Group wiki. The Communications Officer is in charge of the logbook, taking into account the recommendations and suggestions of all the members of the group. The logbook has a cognitive function: it collects all the knowledge and the abilities acquired during the mission.

Phase 10: Personal Diary

Beyond the Group Logbook, each student may use a Personal Diary, with a metacognitive and affective function: Professor Garcia encourages each one to take notes about their feelings and difficulties and how they have been solved. The Diary is implemented using some Short essay question along the Lesson that guides the story.

4 Experimentation and results

The Learning Activity described above is the outcome of a first prototype, experimented with 23 students attending the 10th grade students of Liceo Scientifico in Pompei (NA, Italy). They have been split into six anonymous groups, each of them composed by four people, except one composed by three people. They could communicate exclusively online, using chats and forums.

The students are required to construct arguments starting from the manipulation of an aerogram (a GeoGebra application), in order to represent a given percentage (20%) of red stone found on a new planet on another aerogram with greater radius. They are required to answer to a related open-ended question: “how does the angle of the coloured part change varying the radius? Justify your answer”, firstly individually, then collaboratively and finally by using the semi-open interactive question.

A linguistic analysis concerning the arguments provided by the students can be found in (Albano *et al.*, 2016). In what follows we analyse some qualitative outcomes and report some excerpts that motivated the changes we made to the first prototype.

All students made correct manipulations, that is, they correctly represented the given percentage on the aerogram. However, this does not mean that everyone was able to do it. Sometimes they got hints from the peers, confirmed by the feedback given by the platform in terms of score, as shown in the following chat protocols:

- S23: do you have any idea on how to do?
- S22: radius 2 degrees 100
- S21: are we all supposed to set the same?
- S22: it is wrong
- S23: it says we are right with radius 3 degrees 72

These cases suggested us to eliminate both scores and feedbacks on the correctness of the answer, because students' attention on the score distracted them from providing proper arguments to support their answer. The following excerpt is relevant from this viewpoint: a student tries to focus peers' attention on the request for motivation, but he/she is completely ignored by the peers, even by the Captain (S6):

- S8: why radius 4?
- S7: how do we motivate the answer?
- S6: it gives me "correct"
- S7: me too, but then we are required to motivate the answer
- S7: what do we write?
- S6: go on

In most cases (16 out of 23 students), there is no argument at all to justify the answer, as in the following one:

- S22: when the radius grows, the angle decreases
- S23: varying the radius the angle increases or decreases according to the movement of the radius on the circle
- S5: the angle does not vary, only the radii vary
- S4: the angle does not vary according the variation of the radius but it does according to the variation of the arch
- S11: the angle remains the same

The lack of arguments to support the answer arisen from the manipulation or their incorrectness led us to introduce questions aimed to foster student's reflections on their choices.

Moreover, even in case of right argumentation, such as:

S13: the angle of the coloured part does not vary as in a circle the angle at the center is always 360° and 20% of 360° is always 72°

The other members of the group write exactly the same sentence after S13 did, so we can infer that they borrowed. Using a Question & Answer Forum, instead of the General one, solves the problem since students can see the posts only after their own submission.

Concerning the Learning Activity flow, looking at the score obtained in the semi-open interactive question and the sentences reported in the subsequent forum, we spotted some incoherence between the sentence constructed with the word-blocks and the ones reported in the forum. In fact, the log file reported that student S11 got a score of $66,67\%$, that means he/she gave a semi-correct sentence (correct answer and wrong argument) but his/her sentence in the forum was correct:

S11: the angle does not change because it is always equal to 20% of the circle angle

The first implementation of the semi-open question gave no information on the constructed sentence. Now the codes it provides keep trace of the blocks and allow recovering the sentence built by the student.

Once more, as already seen, probably, the above correct sentence in the forum was borrowed by the student looking at the peers' answers, as highlighted by some chat excerpts:

S12: I can read them; I read S10's answer

S10: in fact, I can read yours

Even student S09 posts on the chat directly the link to the forum:

S09: <http://moodle.diima.unisa.it/moodle/mod/forum/discuss.php?d=158#p323>

Again, we solved the problem adopting a Question & Answer Forum.

In general, the protocols highlight that, at the beginning, most of the students are not familiar with argumentation and do not care about it until they are forced to produce one by means of the word-blocks. This is why we introduced phase 5, where each member of the group is expected to collaboratively construct and agree on a text that gives reason of the correctness of their own. Moreover, in order to interiorize the practice of providing arguments to support own ideas,

we introduced the “experts” peers who are asked to use arguments to explain the reasoning he/she did in order to support mates in troubles.

Finally, we want to discuss the case of an interesting group. As far as fostering argumentation is concerned, this group worked effectively, as shown in the following. At beginning, no one argues at all:

S23: Varying the radius, the angle increase or decreases according to our movements of the radius on the circumference

S22: more the radius is greater than the angle decreases

Then, they were involved by the activity, so they agreed the answer in chat and really tried to convert their sentences into the word-blocks (as required), facing some difficulties:

S21: there are no suitable words

S23: as the angle decreases, is it inversely proportional to the radius?

S21: eh, I think it is ok

S23: then we all use the same word-blocks

Looking at the forum protocols, we found the following two sentences:

S22: the angle increases as it is inversely proportional to the radius but the scientists do not agree

S21: as the angle decreases, it is inversely proportional to the radius

Even if the answers were wrong, the activity actually “worked” with respect to the focus on the argumentation: students started without arguing and the word-blocks forced them to convert their answers into arguments.

This is interesting because we can conclude that the activity is successful with respect to argumentation, but in case of lack of knowledge (for instance, confusing the concept of angle with a sector of the circle) it is necessary to fill the gap. This is why we introduced phase 8, where an external expert may be invoked and help in such cases.

Conclusions

In this paper, we reported the design and the implementation of an online Learning Activity concerning argumentation in mathematics, embedded in a Digital Interactive Storytelling. The template is based on a Vygotskian approach integrated with a discursive methodology to mathematics learning, exploiting peer interactions as well as exploration by means of interactive graphical objects. The design has been refined using a pilot classroom experimentation of the ongoing prototype. Thus some initial choices have been modified (e.g.

introduction of a role for each member of the working group in order to foster the engagement and the responsibility, moving from chat to forum in order to support moving from colloquial linguistic registers to literate ones, interactions among students of various team in case of a whole team in trouble, etc.). Anyway, the qualitative analysis of the protocols of the experimentation make confident that the Learning Activity model is effective to foster argumentation in mathematics.

We plan to design more learning activities based on this cooperative learning model.

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