User-friendly interfaces for Vygotskian computer-based learning activities

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ABSTRACT [1]

In this paper, we present the Learning Interface for Mathematics Education (LIME) project. The main goal of this project was to create User-Friendly Interfaces (UFI) for Vygotskian computer-based learning activities (VCBLAs) in order to promote their dissemination in the school context. A VCBLA is based on collaborative scripts, according to the Vygotskian perspective, and is implemented on e-learning platforms (such as Moodle). It is aimed at the development of argumentative and problem-solving skills in mathematics, and in other educational contexts or for vocational training. Based on VCBLAs testing and studies in the literature, we have identified the requirements for UFI in order to increase users' (i.e., students and teachers) acceptance to enable large-scale testing and use of VCBLAs.

Keywords: Mathematics education, Learning Interface, Collaborative Scripts, e-Learning, Moodle, User Acceptance

1. INTRODUCTION

Many studies have highlighted how collaborative learning can foster the development of problem solving and critical thinking skills in students [1, 2], even in computer-based environments [3]. Students, interacting and communicating with each other, ask questions, provide explanations, justifications, and counter arguments. Such interaction can promote the acquisition of individual skills [4] and, in accordance with socio-cultural theories, the internalization of collaborative practices [5], the enhancement of self-esteem and motivation, and the development of social skills [6, 7].
Collaborative learning can also be partially or fully computer mediated. In such a case, it is referred to as Computer Supported Collaborative Learning (CSCL). In CSCL environments, students can learn on the web [8], join online discussions [9], and write jointly using shared documents or wikis [10]. This can foster a co-construction of knowledge [11].
Despite the benefits of collaboration, however, it is well known that free collaboration does not systematically produce learning [12] because students rarely spontaneously engage in "high-level" collaborative processes in the absence of guidance [13]. Collaboration has to be explicitly proposed in order to produce effective learning [14, 15, 16], especially in computer-based environments. However, providing students with only simple instructions regarding group activities only guarantees collaboration at a basic level [17, 18]. Therefore, in order to induce adequate cognitive processes, it is necessary to appropriately design and structure collaborative learning activities through collaborative scripts, i.e., establishing roles and actions for participants, and regulating interaction within groups [19]. The construct of script originates from cognitive psychology and identifies an internal memory structure that defines a sequence of roles to assume and procedures to follow [20]. In the educational context, a script identifies an externally imposed structure in order to foster learning [21]. Collaborative scripts are often used in computer-based environments, where the need to properly structure collaboration is higher. In recent years, several collaborative scripts have been designed and implemented in CSCL environments to promote the development of argumentative and communicative skills in students [22], for mathematics learning [23, 24, 25, 26], but also in vocational education and training [27].
However, there is a link between meaningful learning and a social process that promotes peer communication and interaction, on the one hand, and internalization of concepts, on the other hand, in accordance with a Vygotskian perspective [6]. In this sense, a collaborative script has to be internalized by students in order to create a meaningful learning.

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We have named Vygotskian Computer Based Learning Activities (VCBLA) educational activities designed and implemented through computer-based collaborative scripts that promote peer interaction, with the goal of being internalized by each student. A VCBLA is usually implemented on an online platform and involves: a narrative flow, which guides the activity; collaboration tools, such as chat and/or forums; possible integration of the platform with external digital applications (e.g., digital applications implemented by means of GeoGebra software and integrated within the platform) [28].
Internalizing a VCBLA could result easier if the script is used for a long time by students. However, computer-based collaborative scripts are often not tested over long periods [29]. In addition, scripts should be characterized by a certain degree of freedom and flexibility [30] in order to improve students' autonomy [12, 31]. However, this effort may not be enough to ensure the dissemination of VCBLAs in school practice. In fact, they might not be used by students, but especially by teachers who should propose them in their classrooms. While research has focused on designing effective VCBLAs for (mathematics) learning, not enough attention has been paid to graphical user interfaces and interface acceptance in educational settings. Indeed, a fundamental and crucial aspect to take into account when implementing user-friendly interfaces is the investigation of the perception, needs and acceptance of these systems by potential users [32, 33].
Our project fits within this context. It is named Learning Interface for Mathematics Education (LIME), whose goal is to engineer VCBLAs through User-Friendly Interfaces (UFI), that is, interfaces that are easy to use, practical and pleasant, such as to arouse the interest of teachers and encourage their effective use in the school.
Our research question is as follows: what aspects and acceptability characteristics should an User-Friendly Interfaces (UFI) possess in order to meet the expectations and needs of potential users, in particular teachers and students?
In this paper we present the LIME (Learning Interface for Mathematics Education) project, whose main purpose is to answer our research question. In the following, we first describe an example of VCBLA for mathematics learning, called Digital Interactive Storytelling in Mathematics (Section 2). Starting both from considerations that emerged as a result of DIST-M experiments and from studies in the literature (Section 3), we attempt to provide a brief description of the goals and steps of the LIME project (Section 4).

2. AN EXAMPLE OF VCBLA

In recent years, several collaboration scripts have been designed and implemented in CSCL environments to promote the development of argumentative and communicative skills in educational context [13], and in vocational training [27].

A significant example of VCBLA in an educational context is implemented as part of the project "Digital Interactive Storytelling in Mathematics: a competence-based social approach" (maddmaths.simai.eu/didattica/digital-storytelling/). It aims to define a socio-constructivist methodology, named DIST-M [34, 35] for designing competence-oriented mathematical learning activities embedded in a narrative framework.
The learning activities are organized into episodes, set in a story context, that represent the basic steps of a mathematician's activity, i.e., the problem-solving process (*exploring*, *conjecturing*, *formalizing*, *proving*, *reflecting*). In each episode, only one group of (four) students play as Actors and the other students play as Observers. Within the Actors group, students take on roles that represent the typical cognitive functions of a mathematician when faced with a problem [36]:

- *Boss*: he/she is concerned with both the participation climate and the actions to be taken according to the purpose of the activity;
- *Pest*: he/she frequently asks questions of his/her peers to verify the consistency of the results achieved by the group;
- *Promoter*: he/she tries to come up with new solutions and ideas to move forward towards the goal of the episode;
- *Blogger*: he/she summarizes the partial and final results achieved by the group and sends them "via email" to the Guru.

The *Guru* is the expert from a Vygotskian perspective, he/she is the one to whom to ask for information and advice in case of deadlocks. This role is usually played by a teacher (or a researcher). Depending on how the narrative evolves within the group of Actors, the Guru may activate/deactivate resources (e.g., spreadsheets or digital applications) to be made available for the student.
The Actors communicate with each other through a Chat room. The Guru has a privileged channel with the Promoter (a private Chat room) through which he/she can interact with the Actors and give advice to overcome difficulties. The other students, divided into groups, play as Observers, assuming roles as well. In particular, each Observer actively observes one of the Actors. In each group of Observers, therefore, there is a Boss Observer, a Pest Observer, a Promoter Observer and a Blogger Observer. Also, the Observers, in each group, communicate with each other through a Chat room. All students, both Actors and Observers, report their remarks in a Logbook.
The roles rotate within each group (of Actors and Observers) and in each episode. In this way each student plays (as Actor or Observer) all roles. This ongoing change of roles aims to foster internalization of both roles (cognitive functions) and episodes (problem solving steps) by each student, in accordance with a Vygotskian perspective [6].

DIST-M is implemented on the Moodle platform (https://moodle.org/). The story is implemented through comic strips (created with the Toondoo web environment and modified appropriately with Microsoft PowerPoint) (Figure 1), embedded in the Moodle *Book* module, which allows the student to enjoy the story by navigating its pages.

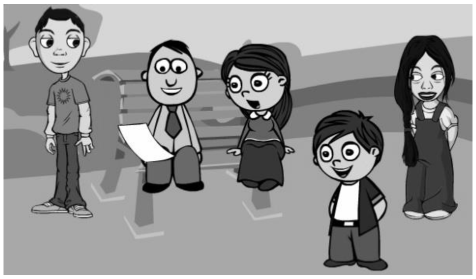

Figure 1. The comics (http://maddmaths.simai.eu/didattica/digital-storytelling/)

The environment is customized to resemble a comic book. Some elements of the Moodle interface are accessible through *Labels*, which provide access to available but "hidden" activities. Chat rooms are implemented through Moodle's *Chat* module. Logbooks are implemented as *GoogleDocs*, embedded within Moodle. Some resources are only made available to students who take on specific roles (using Moodle' *Terms of access*). For example, the private Chat between Promoter and Guru is visible only to the student with the Promoter role, or the Moodle *Questionnaire*, which simulates the Blogger sending the email to the Guru, is visible only to the student with the Blogger role.
Some digital applications, implemented with GeoGebra software and integrated within Moodle [28], can be activated/deactivated by the Guru and made available to the Actors, depending on their interactions within the group Chat. An example is given by the Interactive Semi-open Question (ISQ) [37] that allows the learner to construct sentences by manipulating and dragging digital language tiles. It can be activated by the Guru to support the student in the steps of *conjecturing* and *formalizing*.

The DIST-M methodology aims to promote the development of transversal skills such as problem solving and argumentation. In this regard, DIST-M could be also implemented concerning scientific, technological, but also interdisciplinary issues.
A specific DIST-M concerning an algebraic modeling problem was implemented and experimented with students in the early years of high school. The experiments seem to show that:

- the narrative framework, integrated with digital semiotic mediators, can motivate, and engage students and encourage the production of conjectures, arguments, and proofs [38];
- the designed digital environment influences students' appropriation of roles, and this appropriation seems to foster the problem-solving process [34, 39];
- the technological (virtual) environment allows the teacher and students immediate and persistent access to much more information than in the real-world context, such as Chat room conversations, which can be recalled and discussed [40].

However, considering the advantages guaranteed by the Moodle platform, a possible limitation concerns the lack of customization of the interface and the excessive essentiality of the graphic aspect.
Despite the effort made to make the Moodle platform more accessible and user friendly, there are still many issues related to graphics, both from the student side (Actor or Observer) and from the teacher side (Guru). Indeed, both students and teachers will have to open multiple browser windows in order to access the tools needed to perform the activity.
More specifically, the Actor student will see the Moodle *Book* with comics in one browser window, the group Chat for communicating with teammates in another window, and the Logbook in yet another. If the Guru has activated resources (such as the spreadsheet or the ISQ) the student will have to view them in a new window. Furthermore, if the student plays the role of Promoter or Blogger, he/she will have to open another window for the private Chat with the Guru or for the *Questionnaire* that simulates sending an email.
The Observer student will also see the comics in one browser window, the group chat in another, and the Logbook in yet another. He/she will not see any resources made available by the Guru but will need to see the group Chat of the Actors he/she is observing.
The teacher could view the comics (or not since he/she should know the story well). However, he/she should simultaneously view the Actors' group Chat, the private Chat with the Promoter, and the Questionnaire, which simulates the sending of the email by the Blogger. Also, depending on how the narrative evolves, he/she should activate/deactivate resources by accessing specific sections of the platform.
These constraints due to Moodle's graphical interface create several resource management problems for both student and teacher, amplified by the inability to manage notifications from Moodle Chat. This means that often both the student and the teacher have to actively view the browser windows with the Chats to check for new messages. These problems emerged during the experiments. The researcher was, therefore, always present at the experiments to provide the necessary instructions for using the platform.

Thus, on the one hand, the Moodle platform offers very useful tools for implementing VCBLA. On the other hand, it has disadvantages from a graphical and interface point of view. These disadvantages could, in the long run, hinder the dissemination of VCBLA in schools since teachers might consider them not user-friendly.

3. NEED FOR GRAPHICAL INTERFACES

Considering the aforementioned disadvantages, there is a need for more equipped interfaces from a graphical point of view. A Graphical User Interface (GUI) is a typology of interface which allows human-machine interaction exploiting visual and graphical information. Using a graphical interface within computerized teaching environments is associated with several advantages, as for instance the possibility to amplify the positive effects of other types of scripts, as shown by Schoonenboom [29]. The researcher investigated the effects of two different types of scripts on students' behavior while dealing with remote group work in the CSCL environment, one type of script consisted in textual instructions and the second one was represented by a structured interface. The study showed that the structured interface not only promotes discussion among students but is also able to enhance the effect of textual instructions. Another advantage of using a graphical interface consists in the possibility to reduce students' cognitive load while struggling with the use of new technologies (such as in CSCL environments) and actively involve them in the process of acquiring new knowledge [41, 42]. Some features of the interface could affect the way in which the user interacts with it, influencing the degree of acceptance toward the interface, or in other words user willingness to accept or reject it. According to Davis [43] and his Technology Acceptance Model (TAM), user acceptance of technological systems is affected by two factors: the perceived usefulness and the perceived ease of use of the system. A well-structured and easy-to-use interface could increase its usability [44, 45]. One of the aspects that influence acceptance is the appearance of the interface. As already showed by studies [46, 47] in which the acceptance of assistive interfaces (i.e. virtual agents, robots and synthetic voices) was tested, the qualities that an effective interface should possess are: pragmatic qualities, related to the ease of use, usability and effectiveness of the interface, hedonic qualities, i.e. the pleasantness and presentability of the interface and the attractiveness of the interface. In line with Nokelainen [48] point of view, an effective interface should be designed taking into consideration the following criteria, essential to facilitate learning in CSCL environments: user's full control on the learning process, student's active learning, cooperative learning, flexibility or in other words the opportunity to personalize the interface. These are "goal-oriented" and "applicable" activities, namely activities focused on developing skills (in particular argumentative and problem solving) that can also be used in different contexts. They provide "added value", in the sense that the contents provided to the student are non-standard (as for example comics) and presented in a non-standard way (for instance through a story). They also allow both students and the teacher to constantly provide feedback. The design and implementation of effective interface also should take into account the following critical factors, identified by Puri [49] which, if neglected, could compromise the success of online learning: the student's involvement in the teaching-learning mechanism and the role of the teacher as a facilitator of this dynamic, the reliability and good functioning of the system (software-hardware) and the design of the interface.

4. LIME PROJECT

In this context the LIME project falls within, whose aim is to develop a methodology which allows the engineering of VCBLA through User Friendly Interfaces (UFI), i.e. interfaces which are easy to use, practical and pleasant, in order to arouse students and teachers' interest, encouraging their effective use in schools. Our idea is, on the one hand, to exploit the potential and tools made available by Moodle platform and, on the other hand, to create a specific effective user-friendly VCBLA interface. The goal of the project consists in developing a prototype of VCBLA interface. In this regard, an UFI prototype for DIST-M (see Section 2) will be developed. More specifically, different interfaces will be implemented, one for the Actors students, one for the Observers students, and one for the teacher. First, the interfaces should allow students and teachers to simultaneously view, in a single browser window, all the tools needed to carry out the activity. Figure 2, 3 and 4 show examples of how the interfaces should be planned according to the role of the user, each interface will be characterized by different tools depending on whether the user is an actor student, an observer student or a teacher. Considering the previously described studies, we aim at develop an interface which is able to provide full control to the user during the learning activities, promoting cooperation among students, and characterized by flexibility, in order to allow users to personalize the interface (i.e. the possibility for the teacher to activate / deactivate resources according to the behaviour and results achieved by the students) and allowing both students and teachers to provide feedback in real time. The aim is to develop an interface that will be user-friendly, practical, easy to use, intuitive and attractive and able to arouse positive feelings in the user. A crucial step will consist in testing users' acceptance of the prototype through the use of a specifically developed tool, the "LIAQ" (Learning Interface Acceptance Questionnaire), which will allow to collect data on participants' degree of experience with technology and difficulties during the use of technological devices; investigate participants willingness to interact with the proposed interface and evaluate respectively the pragmatic, hedonic qualities and the attractiveness of the interface. This tool will be the version of the Virtual Agent Acceptance Questionnaire (VAAQ) [32, 50] developed inside the EMPATHIC Research & Innovation project (H2020) and adapted to the assessment of learning interfaces.

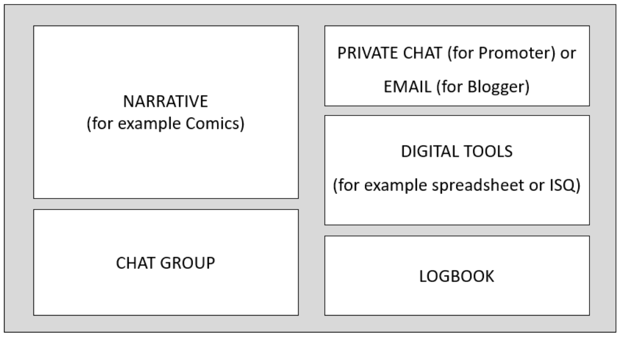

Figure 2. Example of Actor student interface

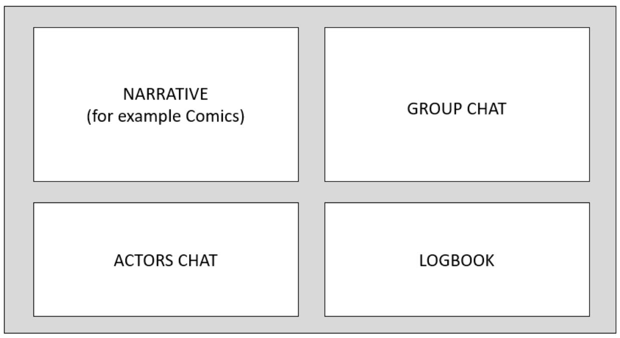

Figure 3. Example of Observer student interface

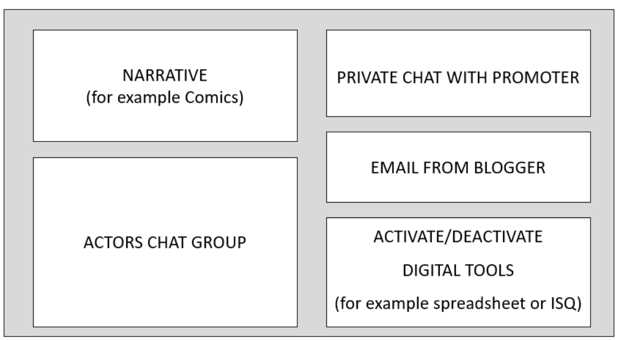

Figure 4. Example of teacher interface

This will be helpful in developing new knowledge consisting of a methodology which allows VCBLA engineering via UFI. The project results could provide guidelines for the developer in order to create effective UFI by taking into account the statistical analysis of the data collected through the administration of LIAQ. The last step will consist in the creation of a second UFI prototype starting from the research results and, therefore, from the methodological guidelines referred to the previous point.

5. CONCLUSIONS

The present work introduced the Learning Interface for Mathematics Education (LIME) project, whose goal is to create User-Friendly Interfaces (UFI) for Vygotskian Computer-Based Learning Activities (VCBLAs). The main aim of the project is to foster the dissemination of VCBLAs in the school context. VCBLAs applications, on the one hand, and studies in the literature on the other hand, have shown that user-friendliness and acceptable graphical interfaces (for students and teachers) are needed in order to achieve this aim. The LIME project could have a strong impact by reducing the gap between educational contexts and the field of scientific research. Teachers could experiment with VCBLAs as new educational methodologies and strategies aimed at developing students' mathematical (or scientifical) skills and transversal ones. Moreover, researchers could collect new data from the experimentation of VCBLAs. The project could also be helpful in extending its results to the fields of business and professional training, in which the development of skills is essential.

6. AUTHORS' CONTRIBUTIONS

The authors equally contributed to the development of the manuscript and all read and approved the final manuscript.

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