Inclusion in Computing and Engineering Education: Perceptions and Learning in Diagram-Based e-Learning Classes with Blind and Sighted Learners

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***Abstract*—E-learning is a modality of education that has been growing all over the world. However, in computing and engineering education programs, the frequent use of graphical representations creates obstacles to the inclusion of visually impaired learners. Besides, many of the strategies and tools used in traditional lectures are not appropriated in e-learning lectures because of the distance among participants. In this context, this paper presents an evaluation of learners' perceptions during e-learning lectures on software requirements specification using UML/SysML use case models, as well as their associated learning assessment. Visually impaired and sighted learners attended on-line lectures in real-time with spatial distance. Participants used an external remote communication tool and some features of Model2gether to communicate and coordinate lecture activities. Model2gether was also used for collaborative real-time interaction with use case models. Learners responded a pre-survey and were interviewed prior to the lectures. After the lectures, learning assessment was twofold: by group work and an exam. Their perceptions were gathered through a post-survey and an interview. The quantitative data was statistically analyzed. The results indicate that, with appropriate tool support, it is possible to include visually impaired learners in e-learning activities based on graphical representations. Moreover, the post-survey indicates that the learners did not recognize their colleagues are sighted or not while collaborating using Model2gether.**

I. Introduction

According to the WHO - World Health Organization, there were about 285 million people with visual impairment in the world [1] in 2014. Their inclusion in some education programs and jobs is challenging and reasons for that comprehend the accessibility of (i) selection exams [2]; (ii) transportation; (iii) educational materials; (iv) pedagogical methods, among others.

In the computing and engineering fields, the frequent use of graphical representations creates additional obstacles to visually impaired learners. Examples of such graphical representations are mind maps [3], entity-relationship models [4], data flow models [5], logic circuits, the UML - Unified Modeling Language [6] and the SysML - Systems Modeling Language models [7].

While the literature on the accessibility of these graphical representations is extensive from the point of view of individual activities [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], many activities conducted in academia and industry have a collaborative nature.

In addition, the existence of solutions for individual activities does not guarantee the possibility of performing collaborative activities, since they involve social mechanisms, namely, conversational, coordination, and awareness mechanisms [20]. These mechanisms are related not only to the level of artifacts (models), but also to the level of non-verbal communication, such as deictic pointing gestures and nodding to agree to someone's argument [21], [22]. All this information compete for the channels available to blind people, generally auditory and tactile.

Considering this, the inclusion of visually impaired learners in education programs and in the labor market is still recognized as a matter that requires deeper research and technological development effort to produce a more inclusive scenario [21], [22], [23], [24], [25], [26], [27].

In this context, this paper presents an evaluation of participants' perceptions during e-learning lectures on software requirements specification using UML/SysML use case models, as well as their learning assessment. After presenting and discussing the results, we present research gaps for future work.

II. Background

A. Inclusion in Education Programs

Amiralian and Masini [28] and Mrech [29] consider two pedagogical conceptions to the inclusion of impaired learners in education programs. The first conception, called normalization, is aimed at making visually impaired learners similar to other classmates. In this conception, the educator is not generally supported by an expert in special education. Impaired learners have to show their ability to attend regular classes. The other conception seeks to understand how they are constituted and perceive the world in order to adapt material and pedagogical methods. This conception does not seek to normalize them or to impose concepts, standards and values of sighted people.

In our work, we adopt the second conception and consider essential the adaptation of materials. In this context, our

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goals of inclusion is that any participant could learn with the proposed activity, been blind or not. In teaching and learning activities, everyone involved is expected to be able to develop the anticipated skills.

B. Collaborative Modeling with Blind People

Collaborative modeling activities are frequent in computing and engineering education programs to teach and discuss concepts, specify and document systems, among others. They involve the creation of models, generally represented as diagrams, that can be used, as an example, to specify software systems, logic circuits, and databases.

In addition to accessing and updating an artifact (model), there are three main types of social mechanisms that arise in collaborative modeling activities as aforementioned: conversational, coordination, and awareness mechanisms.

Conversational mechanisms involve both verbal and non-verbal communication. The latter includes deictic gestures, such as pointing to a model element and nodding to agree with someone else. Pointing to an element is a common gesture used in collaborative activities to indicate an element which someone is mentioning. Nodding can be used to indicate agreement and understanding. Therefore, one should define strategies for non-verbal communication while defining conversational mechanisms.

Regarding coordination mechanisms, one can establish a classification into two categories: master-slave and master-master [30]. In the master-slave coordination mechanism, one of the participants takes the activity control, while in the master-master both participants share the activity control. In the case of a master-master coordination, there are different strategies regarding editing possibilities for each participant. One possible strategy involves maintaining a shared cursor among the participants. Thus, when considering graphical models, only one element of the model can be edited at a time. Another potential strategy involves allowing each participant to freely change the model elements. Furthermore, it is possible to establish locks at different levels, to prevent two or more participants from editing the same element. Although the master-master coordination is possible in activities with graphical models, a master-slave scenario in which there is a constant alternation between the roles of participants is more common. As an example, when a member of a team (master) explains details about a model, others (slaves) follow the explanation. Then, if other member needs to make any contribution, the person can take the role of master.

Awareness, in turn, is related to the knowledge about what is happening and what others are doing. This mechanism can be hardly impacted by the coordination and conversational mechanisms. For instance, when a master-master coordination mechanism is adopted, the volume of information available about the changes in a model could be huge if each participant can freely change the model elements.

C. Use Case Models

We chose to adopt use case models for the lectures because of their simplicity. They are UML/SysML models that may be used to represent a system behavior from the point-of-view of external entities, for instance, users. Use Case models specify the entities roles that interact with a system (known as *actor*) and the system functionality that are valuable to these entities (known as *use case*). These elements are related through associations, dependencies and generalizations. *Association* is a relationship that specifies an interaction between an *actor* and a *use case*. *Dependency* is a relationship that establishes conditional and mandatory extension points between *use cases*. *Generalization* (or *Inheritance*) is a relationship that specifies that a *use case* is a specific version of another one or that an *actor* interacts with the same *use cases* that other *actor* interact with.

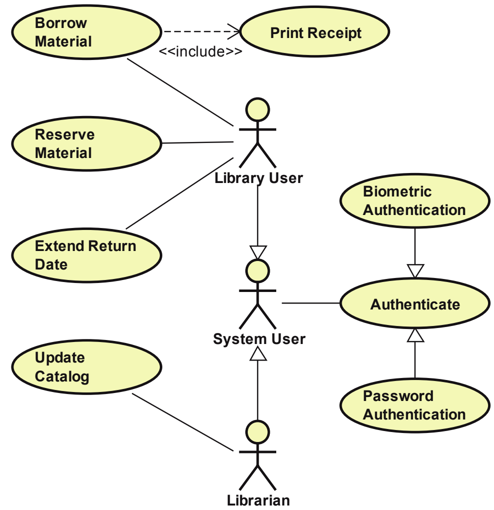

Fig. 1. Use case model for a library system.

As an example, we present a Use Case diagram for a library system in Figure 1. The diagram describes the system functionality by specifying that a librarian may update the material catalog, a library user may reserve materials, borrow materials, and extend the return date. Whenever a material is borrowed, a receipt is printed. Both the librarian and the library users may authenticate themselves to the system. When an authentication is required, this may be done by using a password or biometry. Formally, the system *actors* are *Librarian*, *System User* and *Library User* and the system *use cases* are *Reserve Material*, *Borrow Material*, *Extend Return Date*, *Update catalog*, *Authenticate*, *Biometric Authentication*, *Password Authentication*, and *Print Receipt*. The *Librarian* and the *Library User* are *generalization*s of the *System User*, as well as *Biometric Authentication* and *Password Authentication* are *generalization*s of the *Authenticate*.

III. Related Work

Winberg and Bowers [24] examined the cooperation between sighted and visually impaired people while playing the game *Towers of Hanoi*. The authors emphasized the importance of providing visually impaired participants with continuous feedback on the game state (awereness). In addition, not maintaining a shared cursor control among participants was also identified as a factor that improves orientation, involvement and coordination of shared activities [31].

Oliveira et al. [25] discussed how visually impaired learners may interact with educators and with graphical content during Geometry and Trigonometry lectures. The authors adressed how to translate deictic gestures made on a whiteboard with static content into a haptic representation.

Metatla et al. [23], [26], [27] proposed a tool, known as CCMi, which allows collaborative editing of graph-based graphical models for sighted and visually impaired people. The tool was developed in Java and allows the visually impaired to interact with the diagram via keyboard and an haptic device (Geomagic Touch[1]). The model is represented in two ways: in its original state (no changes) and hierarchically. The authors implemented concurrent access to models by locking means. Aside from this, no other mechanism to regulate the cooperation was implemented. Despite that, the authors give many valuable recommendations for implementating other mechanisms. According to them, an important issue is the lack of representation of the partner's actions in their respective views of the system (awareness). This means users found it difficult to keep track of the actions the other participants were performing.

Kunz et al. [21] described a system (CoME) that supports the inclusion of blind people in brainstorming sessions. The authors' main contribution was related to investigating collaborative aspects in dynamic content. The system allows blind users to access both "artifact level" and "non-verbal level" information through a Braille display. Pölzer et al. [22] presented the users' opinions about studies conducted in trios (2 sighted and 1 blind participant) with CoME. The studies aimed at collaboratively creating mind maps. Both artifact and non-verbal communication were established. Leap Motion was used to detect deictic pointing gestures. A tree-view of the mind map was presented to the blinds and Braille displays were used in the tests. Although speech output could be used with the developed interface, the authors tested only Braille displays.

Among the gaps in the literature regarding collaborative modeling involving blind people, we can cite the need of: appropriate interface/interactions styles in collaborative settings to present model-based information to visually impaired individuals; how information overloading can be avoided in such scenarios; methods that can be followed to make such inclusion possible; among others.

Our research in the field [32], [33] started with the definition of a set of user requirements to include blind individuals in collaborative e-learning activities. These requirements can be divided into three groups: those related to accessibility issues, those related to awareness issues, and those related to communication issues. In order to validate the requirements, we also developed a tool that implements them [34], [35]. In this paper, we go further in our research and use this tool to evaluate learners' learning and perceptions in a collaborative educational setting.

[1]Formely known as Phantom Omni.

IV. E-LEARNING LECTURES

In order to evaluate the learners' learning and perceptions regarding diagram-based lectures with blind and sighted individuals, we conducted two series of e-learning lectures on software requirements specification using UML/SysML use case models. Each series of lectures was attended by one blind and 4 sighted learners, totalling 10 participants in the two series. This number of participants is typical in studies involving individuals with specific impairments [21], [25].

A. Participant Recruitment

Participation was voluntary. The blind individuals were invited through a discussion list of blind programmers. The eight sighted individuals were invited through alumni lists of the authors institutions.

Participants were asked to answer a questionnaire about their profile. The questions were about their: (i) age; (ii) gender, (iii) previous experience with screen readers (for blind participants); (iv) previous experience with the model addressed and its related concepts; (v) blindness condition - since birth or acquired later (for blind participants); and (vi) previous experience in computing or engineering courses. Tables I and II shows the participants' profile. In it, NU means "never used".

B. Supportive tool

In order to conduct the study, we used a free tool we developed, named Model2gether, available at http://www.matematica.br/model2gether. The current version implements also a server side to register users, sessions and diagrams, as presented at the figure 2.

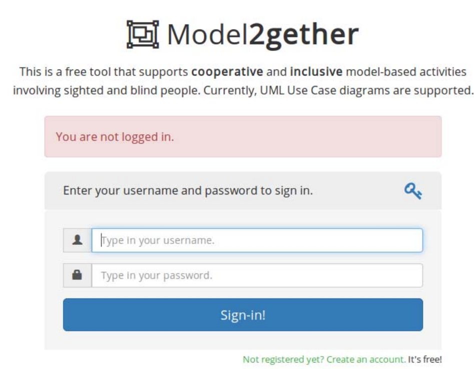

Fig. 2. Model2gether server side to manage system users, sessions, and diagrams

The tool implements interfaces for blind and sighted users: a screen-reader compatible interface for blind users (Figure 3) and a graphical interface for sighted users (Figure 4). Both interfaces present mechanisms for allowing conversational, coordination, and awareness during collaborative modeling activities. In the interface for visually impaired individuals, models

TABLE I
1ST SERIES PARTICIPANTS' PROFILE (NU MEANS "NEVER USED")

Participant	Age	Gender	Blindness	Previous Experience with Screen Readers (in years)	Used Screen Reader
#1	22	Male	Completely Blind	11	NVDA
#2	43	Male	Sighted	NU	NU
#3	24	Male	Sighted	NU	NU
#4	22	Male	Sighted	NU	NU
#5	20	Male	Sighted	NU	NU

TABLE II
2ND SERIES PARTICIPANTS' PROFILE (NU MEANS "NEVER USED")

Participant	Age	Gender	Blindness	Previous Experience with Screen Readers (in years)	Used Screen Reader
#6	40	Male	Completely Blind	10	NVDA
#7	25	Male	Sighted	NU	NU
#8	21	Male	Sighted	NU	NU
#9	24	Female	Sighted	NU	NU
#10	23	Male	Sighted	NU	NU

are specified by a DSL - Domain Specific Language [36]. The elements that may be modeled by the DSL are: actors, use cases, associations, dependencies (inclusion and extension), as well as actor and use case inheritance (Table III). Interaction user-system is possible through shortcuts, a combination of modifiers and keys (e.g. Ctrl+Shift+Alt+A at the diagram edition to create a new actor), and keyboard navigation.

TABLE III
LIBRARY SYSTEM DIAGRAM SPECIFIED BY THE MODEL2GETHER DSL

```
Use Case Diagram "Library Borrowing System"
Actors
   "Librarian",
   "Library User",
   "System User".
Use Cases
   "Borrow Material",
   "Update Catalog",
   "Reserve Material",
   "Extend Return Date",
   "Print Receipt",
   "Authenticate",
   "Password Authentication",
   "Biometric Authentication",
Relationships
   "Borrow Material" include "Print Receipt",
   "Librarian" associates with "Update Catalog",
   "Library User" associates with "Borrow Material",
   "Library User" associates with "Reserve Material",
   "Library User" associates with "Extend Return Date",
   "Library User" inherits from "System User",
   "Librarian" inherits from "System User",
   "System User" associates with "Authenticate",
   "Password Authentication" inherits from "Authenticate",
   "Biometric Authentication" inherits from "Authenticate".
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The interface for sighted users shows use case models in their diagrammatic format (Figure 4) and interaction user-system is possible using mouse and keyboard. Additionally, there are shortcuts to navigate the history of actions other users performed. The only requirement to execute the tool is an HTML5-compatible web browser.

Furthermore, it implements a master-master coordination mechanism, in which all participants share the activity control. In order to allow blind users to control the amount of information they receive regarding model changes, the interface presents the possibility to choose the way they receive the information about changes in the model. This is made by selecting one, two or all among the options: "follow model updates", "Listen to beeps when changes are made to the model", and "allow real-time changes on the textual model representation".

C. Awareness for the blind learners

Continuous awareness was used while the instructor was teaching the content and while the blind learner was working with other learners in a group. Therefore, every time a user changed the model (visual changes, such as moving and resizing, are not reflected to blind people) or pointed to an element, the blind learner listened to beep and audio messages (e.g. "A new use case was created: Borrow Material"). The awareness audio messages produced by Model2gether use the TTS - Text-to-Speech technology available in web browsers.

D. Preparation

In order to coordinate the lecture, we use a synchronous communication mechanism. However, to conceal the presence of sighted or blind participants, we used the communication mechanism without any video image.

As aforementioned, before the lecture, participants were asked to answer a questionnaire about their profile.

Additionally, they had to answer the following questions to assess their previous knowledge about the subject.

1) What are system requirements?
2) What is the difference between functional and non-functional system requirements?
3) What are actors in use case models?
4) What are use cases in use case models?
5) What are associations in use case models?
6) What are dependencies in use case models?

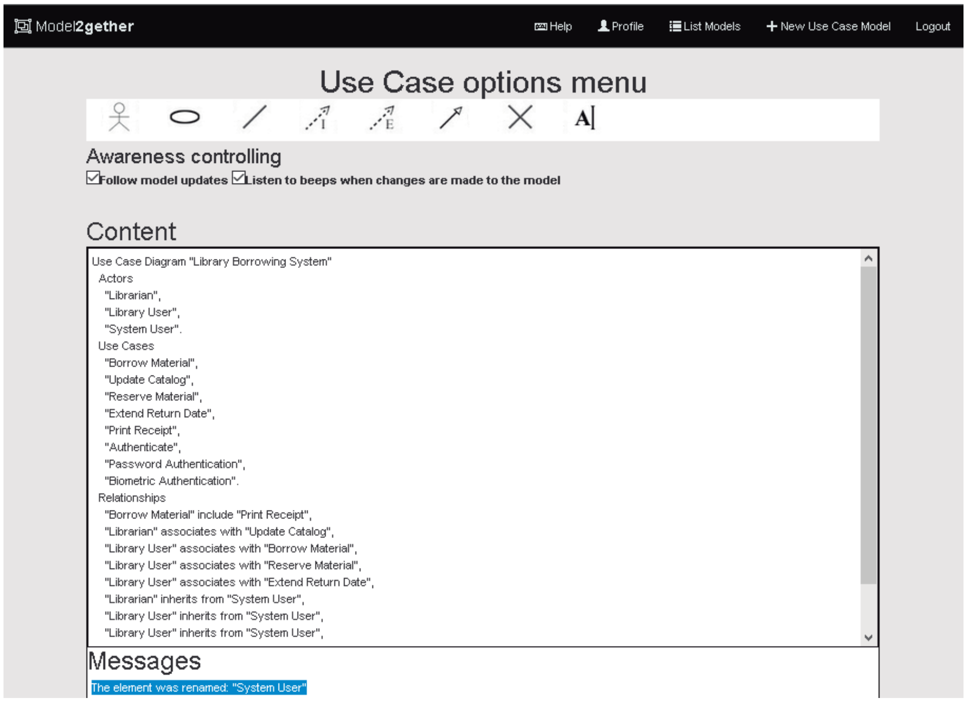

Fig. 3. Model2gether textual user interface

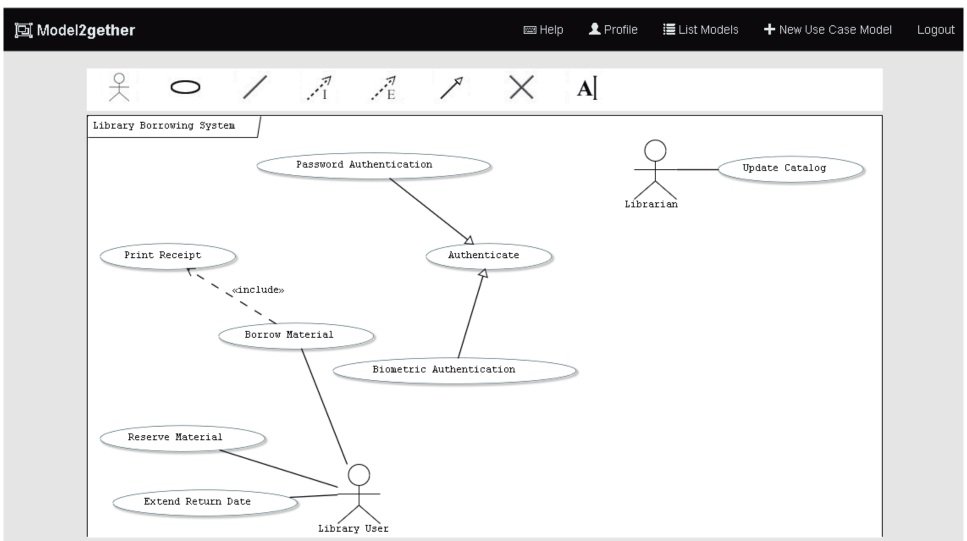

Fig. 4. Model2gether graphical user interface

7) What are generalizations in use case models?

Their answer were assessed and they received a grade from 0 to 10.

To get familiar with the tool, we invited participants to conduct a preliminary use of the tool. For this, they were asked to carry out the following activities: (i) open the tool website and create an account; (ii) sign-in into the system; (iii) find the help menu, open and read it; (iv) open a use case model that was shared with them and read its content; and finally (v) make a change in the model.

E. Lecture dynamics

Before starting each series of lectures, the instructor gave an overview of what would be done. He explained that they would have lectures about requirements specification using UML/SysML use case models and, after that, they would work in groups of three learners in an activity. Each series was composed of 3 lectures of 40 minutes each, totalling 2 hours of lectures for each series.

The participants were allowed to make questions at any time. During the lecture, the use case model purpose and importance were discussed. After that, the use case model elements were presented in the following order: use case, actor, association, dependence (inclusion and extension), and inheritance. Each element, had its definition and semantic in the model discussed. Then, following the participants' suggestions, a Use Case model for a library system was created.

After the lecture, participants had to work in group in a system modeling. To perform the group activity, they received a restaurant order system description to model using use cases. The features were divided equally among the participants and each one had to create the actors, use cases, and relationships related to the features received.

Finally, participants had to answer a post-lecture questionnaire with questions about inclusion and learning. The questionnaire was composed by open-ended questions, Likert-scales (from "strongly disagree" to "strongly agree"), and one related to the general perception about Model2gether accessibility (from "very bad" to "very good").

To the blind participant, the questionnaire was composed by 20 items, 5 of them were Likert-scales, 1 about Model2gether accessibility (from "very bad" to "very good"), and the other 14, were open-ended questions. Among the questions were: (i) Explain what you understand by 'inclusion'; (ii) In relation to your understanding of inclusion, consider the statement "I consider myself included in the lectures" and select one of the following alternatives (Likert-scale); (iii) Explain the reasons of your answer in the previous question; (iv) Considering your understanding of the lecture content, evaluate the following statement "I understood the content taught in the lectures" (Likert-scale); (v) Regarding your understanding of inclusion, evaluate the statement "I considered myself included in the group activity with other students".

To the sighted participant, there were 12 questions, 1 of were Likert-scales, 1 about Model2gether usability, and the other 10 were open-ended questions. Among the questions were: (i) Considering your understanding of the lecture content, evaluate the following statement "I understood the content taught in the lectures" (Likert-scale); (ii) Can you definitely indicate if at least one of your co-workers was visually impaired?; (iii) If you have already attended a use-case lecture, what was the change in the dynamics in relation to these lectures?

Also, they answered the same questions about their subject knowledge aforementioned to check their learning after the lectures. Their answer were assessed and they received a grade from 0 to 10.

V. Results

Among the 5 participants of the first series of lectures, 3 of them (representing 60%) were evaluated with grade 5 or lower in relation to their previous knowledge about requirements specification and use case modeling. The other 2 participants were scored 6.7 and 7.1. The most common errors of the participants concerned relationships between use cases, especially dependency and generalization relationships. After the lectures, all participants increased their grades. The average increase for the first group was 2.3 points. Each participant score is presented in Table IV.

TABLE IV
Participants' grades before and after the lecture.

Participant	Grade before (previous knowledge)	Grade after
#1	3.9	7.5
#2	7.1	7.1
#3	5	8
#4	6.7	7.5
#5	3.2	7.5

The diagrams produced in the group work presented no errors and were suitable for the specified system description. These results show that the lectures contributed to the participants' learning about the subject.

With regard to *inclusion process*, the visually impaired participant of the first series was asked about what he understands by inclusion and whether he felt himself included in the lectures. According to him, inclusion can be defined as "the possibility of carrying out activities under equal conditions. This does not mean doing the same thing as another person in the same way, but rather is related to maximizing the inherent abilities and perceptions of each."

Considering accessibility, he strongly agreed (5 in a scale range from 1 to 5) with the affirmation "I felt myself included in the lectures and group work". Besides, he strongly agreed with the affirmation "I understood the lectures content".

The most interesting result was that none of the sighted participants noted that there was a visually impaired participant in the lecture and in the group work, indicating that the tool gave the necessary support to the blind individual in order to increase his abilities and perceptions. Still regarding the used tools, participants evaluated that the coordination and visibility mechanisms of Model2gether contributed to the conduction of the lecture.

For participants who have already attended lectures on the same subject in face-to-face courses, no difference was noted in the classroom dynamics due to the participation of the visually impaired.

For the second series, among the 5 participants, 2 of them (representing 40%) were evaluated with grade 5 or lower in relation to their previous knowledge about requirements specification and use case modeling. The other 3 participants were scored 5.3, 6.4, and 7.1. The most common errors of the participants also concerned relationships between use cases, especially dependency and generalization relationships. After the lectures, all participants increased their grades. The average increase for the second group was 3.3 points. Each participant score is presented in Tables V.

With regard to *inclusion process*, the visually impaired participant of the second series defined it as "Inclusion is a process by which people, even with their particularities that differentiate them from the group to which they belong, can move around in the spaces, participate in the activities, with the best possible condition, since the spaces and activities were designed for this purpose, or adapted.."

TABLE V
2ND SERIES PARTICIPANTS' GRADES BEFORE AND AFTER THE LECTURE.

Participant	Grade before (previous knowledge)	Grade after
#6	4.3	6.3
#7	7.1	10
#8	4.3	10
#9	6.4	10
#10	5.3	7.8

Considering accessibility, he agreed (4 in a scale range from 1 to 5) with the affirmation "I felt myself included in the lectures" and neither agreed nor disagreed (3 in a scale range from 1 to 5) with the affirmation "I felt myself included in the group work". According to him, the reason for the grade 3 regarding the group work was the perception of auditory overload due to many messages coming from many people and many channels. He agreed with the affirmation "I understood the lectures content".

As for the first group, none of the sighted participants in the second group noted that there was a visually impaired participant in the lecture and in the group work, reinforcing that the tool gave the necessary support to the blind individual in order to increase his abilities and perceptions.

Additionally, for participants in the second group who have already attended lectures on the same subject in face-to-face courses, no difference was noted in the classroom dynamics due to the participation of the visually impaired.

The results indicate that the tools used allowed the visually impaired participant to learn and work together with sighted individuals without affecting the common dynamics of a distance education scenario.

VI. CONCLUSIONS AND FUTURE WORK

In this paper we presented the results of a lecture about UML/SysML use case models involving blind and sighted users. The lecture used the free system Model2gether, whose target is the collaborative work with both kind of users.

The lecture participation was voluntary, no reward was given. The first session counted with 5 participants, 1 of them blind. The second session also counted with 5 participants, one of them blind. It was used pre and post-test.

It was detected an improvement in the participant grade concerning the pre and post-test of 2.3 points in the first group and 3.3 points in the second group.

Information overload in the auditory channel was mentioned by the blind participant of the second series in the group work. It indicates that research related to multimodal interface and interaction styles is important to support collaborative work in master-master scenarios. As only one participant was in control of the activity during the lectures, information overload was not observed during the lectures.

The sighted participants did not note that there was a visually impaired participant in the lecture and in the group work.

The results indicate that the tools used allowed the visually impaired participant to learn and work together with sighted individuals without affecting the common dynamics of a distance education scenario.

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