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Teacher Professional Development via a MOOC on Assistive Technology for Visually Impaired Students Learning Mathematics

Margherita Piroi
Università di Torino e Politecnico di Torino
Carola Manolino
Università della Valle d'Aosta
Tiziana Armano
Università di Torino
Eugenia Taranto
Università di Enna "Kore"
Anna Capietto
Università di Torino

In this paper we describe an Italian MOOC (Massive Open Online Course) for secondary mathematics and support teachers designed specifically to offer different accessibility solutions for visually impaired students of digital curricular resources with STEM content. Different assistive technologies were available in the MOOC from an inclusive perspective (to support the learning of all students, not just those with visual impairments). Using a Meta-Didactical Transposition (MTD) framework, we describe how the contents presented in the MOOC influenced the attending teachers' praxeologies with respect to the implementation of inclusive activities. In particular, we analyzed teachers' lesson designs, proposed in the form of a homework in the MOOC, to detect recurrent elements shaping inclusive didactical praxeologies. We present the result of this coding process and the analysis of four teachers' design as case studies, highlighting how different agents—activated by the MOOC at a micro-level—originated at a macro-level inclusive praxeologies, with respect to choosing assistive technology use in the classroom.

***Keywords*:** Accessibility, assistive technologies, MOOC on STEM content, professional development, visual impairment

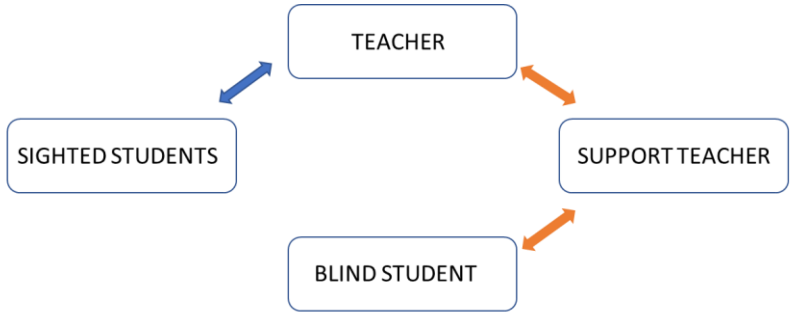
The "Sergio Polin" Laboratory of the "G. Peano" Department of Mathematics at the University of Turin (Italy), works with the aim of ensuring the right to education for people with motor/sensory disabilities and Specific Learning Disorders (SLD). In particular, the Laboratory studies, develops, and disseminates solutions to the problems of accessibility of digital educational resources with STEM content (e.g., content containing formulas, graphs, tables, diagrams).

During the Covid-19 pandemic period, the use of exclusively digital educational resources by people with disabilities and SLD, who need to use assistive technologies and compensatory tools (Federici & Scherer, 2018), has often been difficult, especially in STEM fields (Marchese et al., 2022). These issues have contributed to an increase in the digital divide for people with disabilities and SLD (Raimo et al., 2021), urging renewed awareness of digital learning environments that develop necessary technological solutions to disseminate existing solutions suitable for an inclusive education system.

An inclusive education system, as described in the background paper commissioned for the Global Education Monitoring Report: Inclusion and Education, is an education system that “fosters everyone’s participation [to] render parallel (even special) education systems unnecessary” (UNESCO, 2020, p. 6). It focuses on the individual possibilities of each person, valorizing them all without exception, and concerns ability-groupings. We support Skovsmose’s proposal of engaging learners in the existing curriculum where “learning in mixed-ability groups provides richer opportunities for learning, as learning is related to processes of negotiating, explaining, and noticing” (in Figueiras, Healy, & Skovsmose, 2016, pp. 19–20).

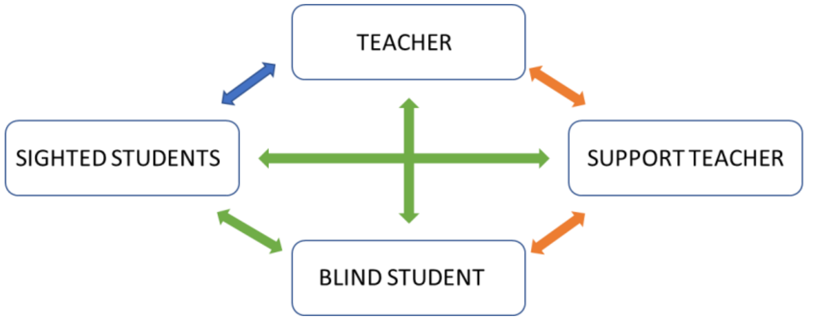
The notion of inclusion goes beyond simple, though preliminary, accessibility. The presence of assistive technologies does not guarantee the inclusion of students with visual impairments in teaching and learning practices (Ahmed & Chao, 2018). Indeed, it merely guarantees, in the best case, the accessibility of content, but the notion of inclusion goes beyond simple, though preliminary, accessibility. Our conjecture was that the presence of such technologies in classrooms, where students with and without visual impairments are together, would be an initial step in promoting new classroom relationships and communication. In mathematics classes, often no direct interaction exists between students, or between the class teacher and students with visual impairments. The relationships and communication are often fully mediated by a support (special educational needs) teacher, and it is known that current teaching practices merely replace visual information with other-sense ones, thus requiring students with visual impairments to ‘act’ like their sighted peers (Ahmed & Chao, 2018). This tendency is represented in Figure 1: our readaptation of a scheme proposed by Moura (2020) to represent interaction patterns in classes with deaf students and a sign language interpreter.

Figure 1
Interaction Patterns in Classes with blind students[1] and a support teacher.



In an inclusive classroom, this pattern would evolve into the one represented in Figure 2, also readapted by us from Moura (2020).

Figure 2
Inclusive interaction patterns in classes with blind students[1].



With the aim of renewing awareness of digital learning environments and disseminating existing solutions suitable for an inclusive education system, intended as above, in the spring of 2022, the Laboratory delivered a free MOOC (Massive Open Online Course), entitled "Accessibility of STEM: Teaching Practices and Technology for the Visually Impaired", via the DI.FI.MA. Moodle platform (https://difima.i-learn.unito.it/). The MOOC aimed to provide both curricular and support teachers with tools and teaching practices for teaching mathematics and physics, especially to students with visual impairments. In particular, the problem of accessibility of scientific content was introduced and teachers were provided with available solutions to deal with it. We observe that, on the one hand, with the use of computers or mobile devices and aids (such as speech synthesis, braille displays and magnifiers), reading and writing well-structured texts without formulas is not a problem for people with visual impairments; on the other hand, full enjoyment of scientific texts

[1] In the scheme we use the simplification "blind students" to mean any student with visual impairment.

containing formulas, graphs, and diagrams, remains an open problem. The handling of formulas, specifically non-linear ones, and objects with special symbols and notations is critical when the use of assistive technologies is needed. A number of solutions for reading, writing, and manipulating formulas and for accessibility of graphs for people with visual impairments exists, some of them developed by the Laboratory. Nevertheless, these solutions were little known by teachers and students, hence our desire to start a MOOC addressing this need.

Description of the MOOC

The design of the MOOC contents is based on the experience of the Math MOOC UniTo Project (Taranto & Arzarello, 2020; Taranto et al., 2020), in which five MOOCs addressed to Italian mathematics in-service teachers have been delivered by mathematics education researchers. Similarly, the first edition of the MOOC "Accessibility of STEM: Teaching Practices and Technology for the Visually Impaired" had been delivered through the DI.FI.MA. Moodle platform, managed by the Mathematics Department at the University of Turin, targeting in-service secondary school (grades 6-13) STEM discipline and supporting teachers from all over Italy. 44% of participants declared teaching students with visual impairments. The MOOC was structured in six modules (0 through 5) delivered over nine weeks.

In Module 0 (the introductory section), the Laboratory and the MOOC instructors were introduced. Participants were given some technical instructions for navigating the online platform, encouraged to introduce themselves on a forum, and answered an initial questionnaire about their experiences with MOOC topics.

In Module 1, the topic of accessibility was presented in general terms. The predominant assistive technologies (braille displays, screen readers, magnifiers, etc.) were described in relation to the use of digital resources by people with different types of visual impairment. The central part of the MOOC focused on the specific problem of accessibility of STEM contents, such as mathematical formulas and graphic elements (later covered in more depth in Modules 2 and 3). Different available solutions for reading and writing formulas were proposed. The chosen technologies to be presented shared the feature of being inclusive: they are not just optimal solutions for students with visual impairment, but can be a useful resource for all students to facilitate mutual interaction in the classroom. The pre-eminent presented solution was LaTeX, a mark-up language for the preparation of texts, particularly used by the scientific community for writing formulae and scientific publications. The functioning in LaTeX is WYSIWYM (i.e., What You See Is What You Mean): a text file with in-line mark-up commands is first prepared, then compiled to obtain a PDF. As a markup language, it is suitable to be handled and read by assistive technologies. Speech synthesis software can in fact directly read formulas written in LaTeX since they are linearized, and more compact and easier to understand than writing it in MathML. LaTeX also has the advantage that it can be successfully used in secondary schools (Armano et al., 2022; Ahmetovic et al., 2021), as coding class-activity to develop students' twenty-first century competencies. In many cases, however, the source LaTeX file is not available. Only the PDF output file compiled in LaTeX can be read, and its mathematical contents are generally not accessible. In 2018 the Polin Laboratory developed the free *Axessibility* package that allows, with the addition of a single line of code in the source LaTeX file, to obtain PDFs with accessible formulas (Armano et al., 2018; Maffia et al., 2023).

Module 4, the main focus of this work, focused on the issue of accessibility of graphic resources (i.e., graphic sonification). It provided an overview of tactile (relief, braille, 3D printers, etc.) and digital solutions for the accessibility of graphics through sonification (which consists of representing graphics by means of sounds). A number of software packages for producing sound graphs, such as *Audiofunctions.web* (http://www.integr-abile.unito.it/en/audiofunctions.web/) and Desmos (https://www.desmos.com/), were presented as solutions to the problem of graphical exploration.

In the final phase of the MOOC (Module 5), some educational reflections were provided (e.g., Bracco, 2015; Fazzino & Taranto, 2022) to enable the design of an inclusive teaching activity by participants. This design activity made use of some of the tools presented during the MOOC modules, which teachers selected. In addition, a final questionnaire was administered to collect satisfaction ratings of the MOOCs, and investigate the learning that took place during the online training.

In each of the modules, there was homework that teachers were invited to carry out. On the one hand, this helped teachers to internalize the topics covered, and enabled them to experiment with the resources proposed. On the other hand, it was a way for the instructors to track how their learning progressed.

This paper focuses on the productions handed in by teachers for the Module 4 homework (described in more detail in the 'Methodology' and 'Appendix' sections). A total of seven lower secondary school teachers and twenty upper secondary school teachers, five of whom are support teachers, handed in their productions (.pdf files and/or applet), forming the data we analyzed for this research work.

Theoretical Framework

Meta-Didactical Transposition (MDT) is a theoretical model elaborated by Arzarello et al. (2014). It has been conceived to describe and analyze the relationship and reciprocal influence between two communities—the community of researchers and the community of teachers—involved in a course in mathematics education for professional development, with respect to their professional practices.

A source for the model is the Anthropological Theory of Didactics (ADT) of Chevallard (1985), especially his notions of didactical transposition and praxeology. The didactical transposition "formulates the need to consider that what is being taught at school (contents or knowledge) is […] something generated outside school that is moved—'transposed'—to school out of a social need of education and diffusion" (Bosch & Gascón, 2006, p. 53). A didactical praxeology (or mathematical organization) is structured in two main levels (García et al., 2006): (a) The "know how" (praxis), which includes a family of similar problems (or tasks) to be studied, as well as the techniques available to solve them (e.g. 2nd degree equations and their solution formulas); (b) The "knowledge" (logos), that is the justifying discourses that describe, explain and motivate the techniques used (e.g., the justification of the formula for 2nd degree equations through the completion of squares or even the theory of algebraic equations).

In the MDT, researchers aim to transpose a certain piece of knowledge, related to the teaching and learning of mathematics, to favor the professional development of the teachers, according to the reference institutions (national curricula, textbooks, etc.). In this case, Arzarello et al. (2014) introduced the notion of meta-didactical praxeologies: They consist exactly of the tasks, techniques, and justifying discourses that develop in teacher education processes. In fact, an educational course generally aims—with the engagement of researchers as trainers—at developing teachers' existing praxeologies, transforming them into new ones, according to the aims of the program. For example, an educational program could be targeted to the introduction of new technologies, teaching practices, theoretical frames by research in mathematics education, new curricula, and so forth. From a discussion about different techniques to address a problem, the teachers could acquire, for example, new ones with a suitable theoretical justification, thus replacing/integrating old techniques and their theoretical support.

Prodromou et al. (2018) describe how it is possible to study the evolution in the teachers' praxeologies at a macro-level, analyzing the interactions between different agents at the micro level. They define *agents* as "the small elements whose interaction contributes to shaping the teachers' praxeologies" (p. 452). Agents are classified as *methodological* if they mainly relate to teaching practices, *institutional* if they refer to ministerial documents (e.g. national curriculum, national assessment) or are embedded in programs proposed by mathematics associations or professional development workshops, *material and technological* when they are linked to the use of specific resources (e.g. paper, pencil, compass, ruler, software, hardware, internet), or *motivational* when they refer to elements that influence actions and that, in turn, might be influenced by teachers' beliefs. Agents may already be present in teachers' praxeologies, or they may be activated during the educational course in which they take part.

In light of this theoretical background, our research objective was to investigate how the content presented in the MOOC influences teachers' praxeologies with respect to the implementation of inclusive activities in the presence of visually impaired students. Therefore, the research questions guiding the study were:

1. What agents appear in the productions designed by teachers, with reference to the contents presented in the MOOC?
2. How do teachers' praxeologies evolve with respect to the presence and/or activation of inclusion-related agents?

Methodology

In order to fulfill the research objective, we needed to analyze the tasks and techniques (praxis) chosen by the teachers and the reasons (logos) behind these choices made to enhance or implement an inclusive interactional pattern in the classroom. We decided to focus on one of the teachers' productions required as homework in the MOOC. Specifically, we analyzed the productions for the homework proposed in the conclusion of Module 4 about graphs sonification. Teachers were given three problems (in picture form), in each of which there was a graph and a multiple-choice question related to the mathematical function that the graph represented. The teachers were asked to choose one of these problems and produce the homework that they would address to their students so that it could be accessible to—real or hypothetical—students with visual impairment. The delivery text for teachers and pictures of the three problems can be found in the Appendix. The first two authors started analyzing the teachers' productions and identified some recurring elements which were coded (see Table 1).

Each code in Table 1 can be seen as associated with one or more agents discussed earlier. For example, an entry "Considerations about constraints" was coded as both institutional and motivational agent, while "Use of knowledge presented in the MOOC" was usually coded only as a material and technological agent, since it was used when teachers considered tools or software encountered in the MOOC in their task design, unless it also manifests a methodological dimension. In the coding process, the researchers also marked teachers' designs that explicitly took into consideration the issue of inclusion, interpreted with the meaning presented in the introduction.

Subsequently, all authors independently coded the different teachers' productions, counting how many times one element in the coding list could be clearly recognized. Codes for which the researchers disagreed were then discussed in order to reanalyze the productions to reach an agreement.

In this paper, we will especially focus on the analysis of elements that allow us to outline an evolution of teachers' praxeologies, in relation to the theme of inclusion, as covered in the MOOC. For this reason, we will analyze in detail the productions of four teachers who will be considered as case studies. For each of them, the agents that had an impact on their praxeologies will be highlighted.

Table 1
Codes with Descriptions

Code	Abbr.	Description
Expectations	EX	They state that they have expectations for further development of assistive technologies that could be helpful in teaching mathematics in an inclusive way.
Constraints (Classroom)	CC	They refer to elements in the classroom (desks setting, timing of lessons, etc.) that could limit or hinder the use of assistive technologies.
Constraints (teacher's work)	CTW	They refer to aspects of their job (amount of work expected, etc.) that could limit or hinder the use of assistive technologies.
Affordances of the software (usability)	ASU	They refer to potentialities of the software chosen in the activity design, with respect to its usability by the students and by him/herself.
Affordances of the software (math)	ASM	They refer to potentialities of the software chosen in the activity design, with respect to the mathematical content to be taught.
Limits of the software	LS	They refer to limits of the chosen software.
Limits of the software (in its chosen use)	LSU	They refer to limits of the chosen software, for the specific purpose it was chosen to be used.
Desire for further training	FT	They express the desire of receiving further training on this topic.
Learned in the MOOC	LM	They decide to use in the activity design a tool that has been presented in the MOOC (Desmos, LaTeX, Audiofunctions.web, etc.).
Change of awareness	CA	They explicitly state that the MOOC has generated a change of perspective or new awareness on the topics of accessibility and/or inclusion.
Prior knowledge (tools)	PKT	They use prior knowledge on tools and/or assistive technologies in the activity design.
Prior knowledge (methodological)	PKM	They use prior methodological and didactical knowledge in the activity design.
Inclusion	INCL	Marked if teachers' designs explicitly took into

	consideration the issue of inclusion

Data Analysis

The demands of the homework of Module 4, in terms of meta-didactical praxeology, can be described as follows:

- Task: Redesign of a task for students, so that it can be accessible to visually impaired students.
- Technique: Choice of the tool(s) and modality of assignment.
- Technology: Usefulness of the chosen tool(s) and modality with respect to the content of the task.
- Theory: The mathematical content related to the task; the practical solutions to accessibility learned in the MOOC (Audiofunction.web, Desmos, etc.); pedagogical knowledge about inclusion.

All 27 teachers who completed the homework developed this praxeology. In line with the codes shown in Table 1, we illustrate here the categorizations of the 27 productions obtained.

As displayed in Tables 2a, 2b, and 2c, “Inclusion” was identified in the work of 11 of the 27 teachers who completed this homework. Here we describe some parts of teachers’ productions that were coded using this label, in order to present the different agents that affected the evolution of the teachers’ praxeologies with reference to inclusive practices. From the 11 teachers, we extract a representative sample, i.e., we consider 1 lower secondary school subject teacher (T1), 2 upper secondary school subject teachers (T12 and T10), and 1 support teacher (T23).

*The case of T1***.** T1 chose to work on the image related to Problem 1 (see the Appendix). She depicted how she would present the problem to her students. Her work was an accessible pdf: screen readers and braille devices recognize (i.e., read) text, formulas, and links to Desmos. The teacher affirmed her appreciation of the graphing calculator software and mentioned: “Because it describes the function by also considering the intersections with the axes, as well as the sound to show whether the function is increasing or not. And in this problem, it is important that the intersection of the axes is indicated, something I felt was missing in Accessibility.web. Therefore, I created a Desmos file for each function and added the link to the images.” The researchers coded this extract as Inclusion, as the links are present in the text behind (attached to) the images of the graphs themselves. The text of the problem is almost completely unchanged from the one proposed, with the only exception of the addition of the sentence: “To answer click on the alternatives and listen to the graphs”, which suggests to the sighted student the existence of the links hidden under the images. The total conformity of the delivery to the original is justified and argued by T1: “I did not want to distort the problem because I hope that one day we will really get to the point where we will have tools that allow us to simply click on educational content and make it accessible. It’s important for the inclusion of students and it’s important for the work of the teacher, who—

indulge us—really has a lot of work to do and cannot think about overhauling a problem over and over again.” In T1, the agent “Affordances of the software (math)” clearly emerges. In fact, she specifies that she prefers the sound (precisely a “pop”) that is emitted by Desmos when two curves intersect, instead of the voice that Audiofunctions.web proposes (e.g., if a curve intersects the x-axis, in Audiofunctions.web we hear “x”). We also noted the presence of two other agents, “Constraint (Classroom)” and “Constraints (Teacher’s work)”, when she referred to the teacher’s heavy workload, limited time, and lack of adequate resources.

Table 2a.
Coding for Lower Secondary School Teachers with T1 Highlighted

	T1	T2	T3	T4	T5	T6	T7
EX	**1**				1		
CC	**1**			1			
CTW	**1**						
ASU		1		1			1
ASM	**1**			1			1
LS	**2**						
LSU		1			1		
FT	**1**				1		
LM	**3**	2	1	2	1	2	3
CA		1					
PKT					1	1	1
PKM						1	
INCL	**X**	X			X	X	

The case of T12. T12 decides to assign Problem 2 to the students via the software Desmos. In the description of the proposed problem, she wrote: “This problem is suitable to be assigned to the whole classroom, as I have described, giving to all the students the same tools.” Then she reaffirmed: “I did not know the graph sonification. Its discovery gave me the chance to think about activities to realize in the classroom even with students without any visual impairment. This is a tool that, in my opinion, helps a lot with acquiring some properties of a graph in a deeper and more stable manner, but at the same time in an amusing way.” It is evident that she paid attention to designing a problem that required the use of tools that could be useful for all the students in her class. In doing so she recognized the inclusive potential of the software, designing what we define as an inclusive activity, and not only finding a solution for students with visual impairments. Here, for example, the use of Desmos can be seen as a technological agent that is activated by the MOOC, and that contributes to shaping an inclusive praxeology.

Table 2b

Coding for Upper Secondary School Teachers, with T10 and T12 Highlighted

	T 8	T 9	**T 10**	T 11	**T 12**	T 13	T 14	T 15	T 16	T 17	T 18	T 19	T 20	T 21	T 22	**T 23**	T 24	T 25	T 26	T 27
EX				1		1														
CC			**1**																	
CTW									1							**1**			1	
ASU		1	**1**	1	**1**	1		1	1		1			1	1					1
ASM		1	**1**		**1**			1		1	1				1	**1**	1	1		
LS			**1**	2		1			1						1		1		1	1
LSU								1				1						2	1	
FT				1		1										**1**				
LM	1	1	**1**	2	**1**	2	1	1	1	2	1	3	1	3	1	**3**	3	3	1	3
CA				1	**1**	1														
PKT			**1**	1		1		1	1			1			1		3	1		
PKM			**1**					1			1	1						1		
INCL		X	**X**	X	**X**				X		X					**X**				

The case of T10. T10 showed how she would have presented Problem 1 to her whole class via the “student screen” feature of Desmos. And she stated: “I would propose the complete test on Desmos to the whole class. In fact, Desmos allows the possibility of sonifying the graph, a possibility that I would present earlier in class, because I find the association of the slope of the curve/sound that increases in frequency very significant and impactful, because it conveys even more explicitly the idea of the linear curve that 'rises' when the angular coefficient is positive and 'falls' when it is negative. […] The use of Desmos for the activity would allow the introduction of a resource such as graph sonification, not only as a resource of accessibility, but as an additional resource for all.” Explicitly, as *educational intentionality*, T10 also states: “I would need it precisely to understand whether the general student (sighted and not) has internalized the concept of slope and knows how to match the negative angular coefficient of the proposed function to a line that ‘falls’ (among the proposed answers there is only one).” Particularly relevant was the teacher’s explanation of the difficulties envisaged: “Obviously I can imagine the chaos that would ensue (but also the amusement of the students!) if everyone from their PCs could listen to the sound interpretation of the line! But I see it as an opportunity for everyone and a great approach for any blind student. So in anticipation of activities and tests, I would suggest that everyone brings a pair of headphones (if not available at school) so that they can take advantage of this tool.” Based on T10’s writing, we identified seven different agents. Considerations of “Constraints in the classroom/school” when she referred to the potential presence of chaos in listening to the software’s audio output regarding the slope of straight lines by all students. She then identified headphones as ancillary equipment. “Analysis of software potential and limitations with respect to both usability and mathematical content" are the agents that emerged during coding when T10 described the interpretation of the concept of angular coefficient through sonification. She considered Desmos to be a tool certainly suitable for blind students, but also for sighted students (in fact, she spoke of it in terms of an "additional resource for all") were outlined as agents relating to the "networking of pre-existing knowledge and knowledge learned in MOOCs", in line with the remarks also made by T12.

The case of T23. T23 produced Problem 1 using LaTeX with Axessibility, then inserted the links to the four graphs created via Audiofunctions.web, "with the aim of making the PDF document with educational content accessible to learners with visual impairments and helping them to be autonomous in carrying out the proposed activities." She mentioned that she had installed NVDA (Non Visual Desktop Access) software[2] on her personal computer to check that the document is properly "read". She proved her commitment to testing the new technologies of the Laboratory and knowledge presented in the MOOC.

Her reflection stated: "These tools are very useful for carrying out inclusive teaching activities for everyone and facilitating learning in scientific fields, removing barriers that were insurmountable until some time ago. The achievement of this educational activity required for me a considerable effort, first of all in understanding to what extent it is better to use the tools provided along [with] this course, secondly I had to change my teaching approach, which is not always easy when certain duties or skills are taken for granted." This reflection denoted an evolution in T23's praxeologies. On the one hand, T23 declared that she considered the tools proposed in Module 4 to be useful, in fact, she remarked by saying that they were capable of "eliminating barriers that were insurmountable some time ago." This denoted an intention to consider them in one's teaching practices. On the other hand, T23 admitted that she had made a "considerable effort" not only in understanding how to use such tools, but also in changing her approach to teaching. It is noticeable here how the agents "Desire for further training" in the professional field and "Constraints (teacher's work)" when she reflected on her workload had influenced her considerations.

An attentive reader might have noticed that of the four case studies, three teachers worked on Problem 1, and only one on Problem 2. Indeed, almost all of the 27 teachers chose to present Problems 1 and 2, discarding Problem 3 a priori. Problem 3 was done by a single teacher only (T25). We believe that this decision to discard the third problem was linked to the fact that the two software packages presented (Audiofuction.web and Desmos), in the presence of circumferences, struggle to generate significant sonifications. Or rather, Desmos would be the preferred software when working with circumferences,

[2] It is a free screen reader. Retrieved from https://www.nvaccess.org or, for the Italian community, https://www.nvda.it/

but sonification is not easy to achieve. T25 was in fact a support teacher who has been working with Desmos for years, most likely affecting her decision to use this problem because of prior experience.

Discussion and Conclusions

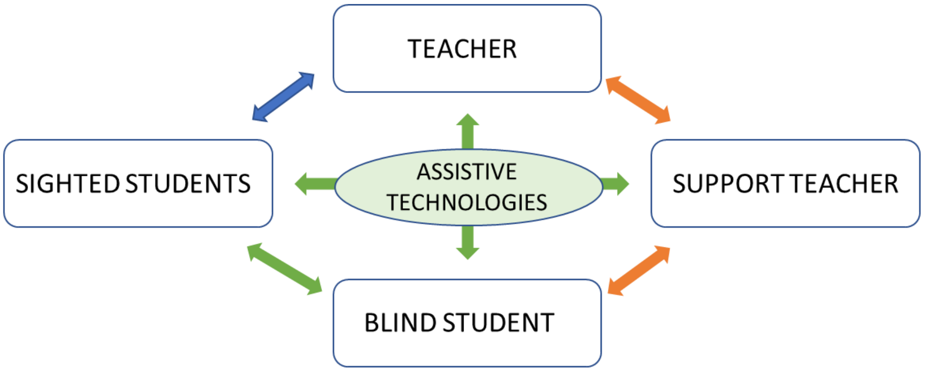
Tables 2a, 2b, and 2c present an overview of the agents related to the contents presented in the MOOC that we have identified in the teachers' activity designs. In order to, at least partially, deepen these results, in the previous section (Data Analysis) we have described how these agents were recognized in some of these productions. One datum that surprised us, was the low number of cases in which the code "Inclusion" was assigned. This resonates with our conviction that considerable confusion still exists between accessibility and inclusion, as evidenced for example by T23's comments about her activity design. When aiming at designing an inclusive activity, the focus often remains on the student with special needs' chance to autonomously approach content, rather than on realizing an inclusive—with the meaning before delineated—activity. Not incidentally and as mentioned previously, T23 was a support teacher. We have observed as a recurrent phenomenon in our work that support teachers tend to focus on single students' accessibility needs, assigning minimal importance to the participation of a whole class in the alleged activity. This is confirmed by the fact that out of five support teachers who have carried out this activity, only one was ever coded as "Inclusive". This result is not entirely surprising, since as already mentioned in the Introduction, support teachers are usually relegated to helping the single assisted students, and there is still little communication and collaboration between them and subject teachers.

Although the attention given to inclusion is lower than we, as designers and instructors of the MOOC, expected, we still believe that this small achievement should be valued. The analyzed teachers' productions where the "Inclusion" aspect was present are particularly interesting, as they give insight into what the elements are that support the formation of inclusive didactical praxeologies as well as those that constrain or limit it. The chosen methodology indeed has consisted in analyzing the different interactions among agents at the micro-level, with the aim of examining, at the macro-level, the evolution of teachers' praxeologies, with respect to the use of assistive technologies in an inclusive perspective. Considering as an example T1, in her production the presence of agents of different types, methodological, institutional, motivational, and mainly technological, is evident. Some of these were possibly present in her praxeologies already before the attendance to the MOOC, some others seem to have emerged during the course. It is the case of technological agents, traceable to the codes "Learned in the MOOC" and "Affordances of the software (math)". Not only is it clear that the chosen technologies have been learned attending the MOOC, but T1 is also able to recognize the potentialities and limits of the choice of one particular software over another, with respect to the mathematical concept to be taught, the class arrangement and the goal of inclusion. We can recognize in this a joint partaking of technological and methodological agents. Institutional agents play an interesting role here. We intend as institutional those agents that are related to the national curriculum and national assessment, as well as other elements, usually constraints, due to the structure of the school system; these could be for example the limited time allocated to a subject teaching, physical constraints of the classrooms, the amount of work that is required to teachers, among others. In T1's work for example we identify this type of agent, that has been indeed coded as "constraint (Teacher's work)", when she states: "[the teacher] has a lot of work to do and cannot think about overhauling a problem over and over again." This institutional consideration has an important function in the shaping of her praxeology. She makes the strong decision to present the problem in the same form as presented to the rest of the class, with the option, for everyone, to "listen" to the graph of the function, instead of substantially modifying the problem.

A motivational agent, that we have labelled as "Expectations", plays an important part here too. Her choice is indeed motivated also by the hope that "one day we will really get to the point where we will have tools that allow us to simply click on educational content and make it accessible."

Figure 3

Inclusive Interaction Patterns, Mediated by Assistive Technologies



In those cases when inclusive praxeologies were recognized, the particular attention given to assistive technologies was noteworthy. These teachers seemed to recognize not only the potential of these technologies in making mathematical content accessible, but also in mediating the relationships between the student with special needs and the whole classroom. These technologies indeed, if properly used in classroom activities design, might be one possible key to the evolution of classroom interaction patterns, surely, as indicated also in many teachers' productions, enhancing the interaction between all students in the classroom and the teacher (Figure 2). One aspect that seems to remain feeble is the type of interaction between the support teacher and the whole classroom. We believe that assistive technologies, again if properly used, can totally reshape classroom interaction patterns, strengthening also these kinds of relationships (Figure 3).

In future our MOOCs or our programs of professional development for teachers, we will certainly give more importance to the use of assistive technologies in the inclusive mathematics classroom. We will try to do this, for example, by enhancing communication between subject and support teachers in the task design activities, also leveraging the affordances offered by the Moodle platform where the course is delivered. A new MOOC on similar topics is planned and intended to be offered to a massive number of participants (instead of the approximately 30 who attended the first iteration). This objective is leading us to redesign the previous MOOC to allow more space for asynchronous interaction and to nurture knowledge connections and communities of teachers (Taranto et al., 2020).

Future research will explore the effective implementation of inclusive activities with the use of assistive technologies in classes with visually impaired students. This will allow us to better study the process of inclusive design, based on the real needs of the students, with their specific level of visual impairment, and on the context of the class with all its students. Such an investigation is also meant to deepen the theoretical stance on inclusion, which might enrich possible future cycles of professional development courses on the topic.

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Authors:

Margherita Piroi, Ph.D., Graduate student
Università di Torino e Politecnico di Torino
margherita.piroi@unito.it
https://orcid.org/0000-0002-6519-8383

Carola Manolino, Ph.D., Assistant professor*
*(*corresponding author)*
Università della Valle d'Aosta
c.manolino@univda.it
https://orcid.org/0000-0002-8711-4638

Tiziana Armano, Research technician
Università di Torino
tiziana.armano@unito.it
https://orcid.org/0000-0002-3550-9240

Eugenia Taranto, Ph.D., Assistant professor
Università di Enna "Kore"
eugenia.taranto@unikore.it
https://orcid.org/0000-0001-6093-6618

Anna Capietto, Full professor
Università di Torino
anna.capietto@unito.it
https://orcid.org/0000-0002-4008-7142

APPENDIX

Final Homework of Module 4 "Accessibility of Graphical Resources"

Here in italic is the final homework of Module 4 as proposed to the teacher-learners, translated from Italian.

As the final homework of this module, we propose that you imagine providing at least one of the three problems below to a student with visual impairment during a Computer-based assessment.
These questions are provided to you in the form of an image and therefore, at this time, they are completely inaccessible.

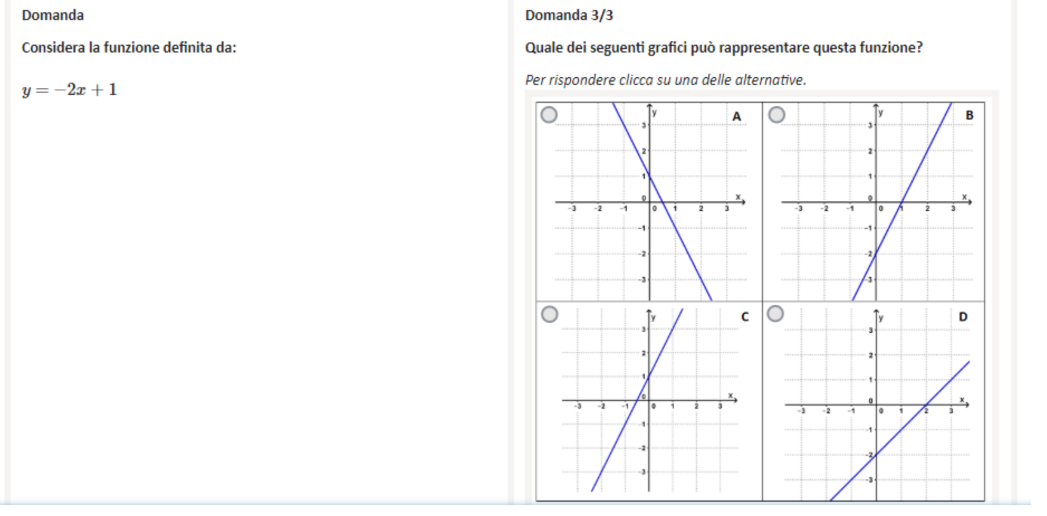
In particular, we ask you to place yourself in the perspective of wanting to leave the student completely autonomous in approaching the solving process, and therefore to provide him a priori with all and only the resources you think the student may need to solve the problem (e.g. audio files, software such as those presented in this module, written text...).
Keep in mind that the student must be put on an equal footing with his or her peers who are solving the same problem at the same time as him.

Try to realize this delivery and upload it here on the platform, accompanied by all the necessary resources.
Then write a short report explaining the choices made and the underlying teaching intentions. If you like, also add some of your own reflections or observations on the difficulties and opportunities encountered.

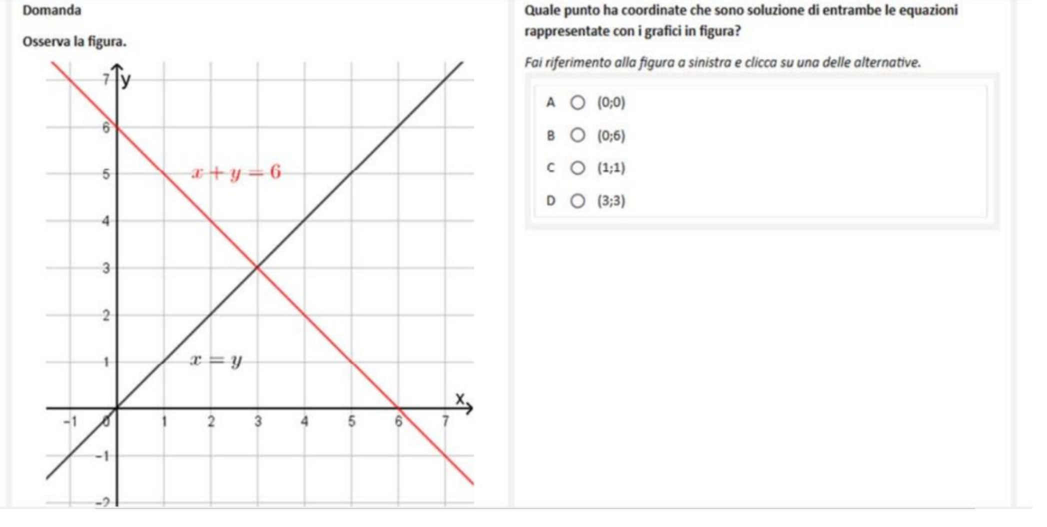
<u>A little food for thought</u>
With this activity, we want to invite you to make a change of perspective.
Therefore, we propose you not only consider the question:
"How can I get the student to understand/approach the question and its teaching content?"
but also
"What mathematical meaning does this representation hold?"
and "How does a person who can see relate to this graph?"

Below are the three problems in image format as provided to teachers:

Problem 1.[3]
Given the function written on the left, identify which of the 4 graphs on the right is the one showing its representation in the Cartesian plane



Problem 2.[4]
Given the graph on the left, ask which of the points listed on the right is a solution of both equations represented in the graph.



[3] Problem retrieved from the Italian National Assessment “Prove Invalsi 2018”, Grade 10.
[4] Problem retrieved from the Italian National Assessment “Prove Invalsi 2019”, Grade 10.

Problem 3.
Given an orthogonal Cartesian axis system Oxy in the plane, identify which of the five figures is the circle whose equation is the one given at the end of the question.

Fissato nel piano un sistema di assi cartesiani ortogonali Oxy, quale tra le seguenti è la circonferenza di equazione $x^2 + (y-1)^2 = 4$?