THE POSITIVE SIDE OF THE PANDEMIC, DOES IT REALLY EXIST?

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Abstract. The immediate shift from face-to-face to distance instruction caused by the Covid-19 pandemic has raised teachers' awareness of the significant role that digital tools can play in educational processes. This shift forced teachers to use different kinds of digital technologies in various ways to overcome the challenges they encountered as a result of the pandemic. In this keynote talk, I will discuss how teachers use digital tools for educational proposes, aiming to extract insight regarding how such tools can be used beyond the Covid-19 period. In addition, I will present innovative approaches towards using digital tools, the need for which arose during the lockdown period, and how these approaches can be integrated into ordinary educational sessions at schools.

Keywords: Digital technology, learning and teaching mathematics, post pandemic.

INTRODUCTION

With the outbreak of the global Covid-19 pandemic in 2019, many workplaces began working under emergency regulations. Schools across the world closed their gates and transitioned, without prior warning, to distance learning and instruction. Many teachers found themselves in a different reality than they were used to. The new reality forced them to change their work practices and deal with difficulties and challenges that they had not experienced before. Teachers found themselves obliged to improvise teaching methods and use new methods to maintain proper teaching practices. Due to the closures and restriction of social interaction, teachers and students had to use various ubiquitous digital technologies (e.g., email, video clips, WhatsApp, Zoom, MS Team, etc.) to communicate with the students and to continue the instruction process. I will point out that these technological tools are not necessarily the strong side of all teachers, and the degree of skill in using these tools differs from teacher to teacher.

This new reality invited many researchers from all over the world to explore the teaching, learning, and evaluation processes that emerged during the Covid-19 period (e.g., Adedoyin & Soykan, 2023; Cusi et al., 2022; Thurm et al., 2023). Many studies have focused on the challenges teachers face as they transition from classroom to remote teaching, looking at how teachers have tackled these challenges and how technological tools have helped them overcome these challenges (e.g., Aldon et al., 2020). In my talk, I will begin by discussing and mentioning some of the challenges that teachers have faced. Second, I will present some methods that teachers have employed to overcome these challenges. In the third part of my talk, I will introduce learning systems that have been developed or are still in the development process, which are endeavoring to overcome challenges that arose during the Covid period. In particular, I will introduce an AI-based learning system that aims to track students' learning processes in real-time, and to inform teachers of prominent characteristics in the learning process or so-called critical moments during learning (Segal et al., 2017). Information about these processes is especially important for teachers who must know what is happening with students who are physically far from away. The second system, called MathematicX, allows the teachers to determine the contents of the lesson, and

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then leads the students in a differential way toward achieving the pedagogical goal set by the teacher. The third system, Dash4Emotion, is a dashboard-based system that tracks a change in students' sentiments and alerts the teacher about the students' emotional status. This system is important because the emotional aspect plays a significant role in a crisis learning period.

CHALLENGES IN THE PROCESS OF LEARNING MATHEMATICS DURING COVID-19

As I mentioned above, the Covid-19crisis surprised educational systems, revealing that some of the teachers were not qualified enough to deal with the demands of teaching under the conditions required by this period. Teachers began to teach in a new reality, accompanied by many challenges. The teachers dealt with the challenges, sometimes with the help of the educational institutes and sometimes alone, and offered solutions to overcome these challenges. The research literature has discussed several challenges, and I have no intention of reviewing them all in this paper. On the contrary, I will focus here on the central themes of challenges that arose from the research literature in order to establish a robust basis that allows me to discuss the role of the innovative technologies that were inspired by or greatly developed during the Covid-19 period. To this end, in my talk, I will focus on several central themes of challenges that have been discussed in Aldon et al.'s (2020) paper: The challenges associated with limiting social learning and applying contemporary teaching methods, challenges related to supporting students who face difficulties, challenges related to identifying student emotions, and challenges related to student assessment.

One of the main challenges teachers met during the Covid-19 period was the limitation of applying collaborative learning, such as learning in small groups, and implementing contemporary teaching methods, such as inquiry-based learning (Aldon et al. 2020). Although online learning platforms, like Zoom or MS teams, allow breakout rooms, the teachers found it challenging to manage collaborative learning. They attribute this challenge to the fact that the teachers cannot be involved in more than one breakout room at the same time. The presence of the teacher in one room for a while prevents him/her from seeing what is going on in the other rooms. Unlike the classroom setting, where the teacher has more control and is more aware of what is going on in several groups simultaneously, online platforms make supervision more challenging, or at least teachers were not practiced in conducting it through this medium.

The shift from face-to-face to remote learning has limited the implementation of contemporary teaching approaches, such as inquiry-based learning, while strengthening the transmission approach of teaching (Aldon et al. 2020). One possible reason for this challenge is the limitation of teachers' ability to guide students' exploration. In this context, research has found that the guiding role of the teacher in supporting students is essential to the effectiveness of inquiry-based learning (Lazonder & Harmsen, 2016). In fact, if inquiry-based learning is interpreted as an approach in which the "learner is not provided with the target information or conceptual understanding and must find it independently and with only the provided materials" (Alfieri et al., 2011, p. 4)—in other words, as learning in which the teacher has no significant role— it has limited educational value (Scott et al., 2018). To overcome this challenge, teachers found themselves adopting a transmission approach to learning, though they were not fully convinced of its effectiveness (Aldon et al, 2020).

A more serious challenge than limiting the application of contemporary teaching methods is the teachers' feeling that they are not engaging in a significant learning process when learning takes place remotely. This is actually a very significant challenge, with teachers feeling they have had to settle for maintaining what students have learned in the past (Aldon et al., 2020). Apparently, due to the inability of some teachers to take advantage of the digital tools available to them or to instrumentally orchestrate the digital tools (Drijvers et al., 2010), they were content with teaching through lecturing. This way of instruction led to a lack of interaction between teachers and students, which resulted in students' boredom and lack of motivation for learning.

Identifying student emotions and regulating them during the teaching process is significant for the success of the learning process. If this claim has been confirmed in ordinary days, it holds even more true in times of crisis, when feelings like fear, uncertainty, frustration, and boredom are common. In distance learning, even if the students' cameras are turned on, identifying students' emotions during the learning process poses a significant challenge. This is one of the findings that has been revealed in studies that examined the challenges teachers met during the Covid-19 period (Aldon, et al., 2020). Teachers, partly due to technical limitations, found it difficult to characterize the emotions of the students during remote learning, and they felt powerless to help students regulate their sentiments to convert them from emotions that hindered learning to emotions that advanced learning.

In a democratic society, educational systems should provide an equal opportunity for every student to learn. This goal is even more critical during a pandemic period, where social and cultural differences can easily manifest. Supporting low-achieving students and students with difficulties was found to be an essential challenge encountered by teachers. More precisely, to help students who face difficulties, teachers were asked to provide materials that help students to follow the lessons at their personal rate. In addition, they were asked to devote time, often after hours, to answer students' questions and to re-explain topics. These are only two examples, among many others, that illustrate the compensatory actions teachers were required to take in order help students overcome the difficulties they face during distance learning.

Assessment, in addition to learning and teaching, is another component of the educational activity. In fact, assessment is always a fundamental concern for teachers. On the continuum between summative and formative assessment, teachers, based on their beliefs and learning assumptions, implement strategies to make decisions about their future teaching (Perrenoud, 1998). The aim of summative assessment is to evaluate student learning at the end of an instructional activity by comparing it against some standard. The aim of formative assessment is to monitor student learning to provide ongoing feedback that teachers can use to improve their practices and students can use to improve their learning. Formative assessment is different from other kinds of assessments in that it is used in the process of learning, not at the end of it. The formative assessment focuses on students' learning processes, collected during teaching and learning activities, to make "decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited" (Black & Wiliam, 2009, p. 7).

Implementing both kinds of assessment has been found challenging for many teachers. Cusi et al. (2022) found that one of the main challenges teachers met during the Covid-19 period was related to different technical problems that prevented them from effectively activating typical formative assessment strategies, such as designing and conducting whole classroom discussions aimed at eliciting evidence of students' understanding. Another challenge associated with formative assessment is related to specific difficulties faced by teachers in following students' processes due to the difficulty of activating multimodal communication. Concerning the summative assessment, Cusi et al. (2022) found that the need to ensure the reliability of the exams and of being sure that students do the exams by themselves, without external help, is one of the main challenges teachers meet. The second main challenge that Cusi et al. (2022) found was related to teachers' difficulties in identifying the right objects of assessment during the Covid-19 period. The teachers, especially those whose students were involved in national final examinations, expressed their worries due to the lack of clarity about the mathematical topics involved in the final examinations and the ways of assessing them.

DIGITAL TOOLS USED BY TEACHERS TO OVERCOME THE CHALLENGES

The commonly used digital technologies (email, video clips, WhatsApp, etc.) played a key role in helping teachers overcome the instructional challenges they faced during the Covid-19 period. To support the transmission approaches to learning, teachers sent the learning materials to their students via email. Others video recorded themselves solving exercises or explaining a new topic and posted their clips via the YouTube platform. A third group of teachers used instant messaging applications to support their students and to help them be engaged in the learning process. In addition, teachers used several video communication platforms (i.e., Zoom, MS Teams, and others) to manage the learning process. They utilized the affordance of these platforms to transmit knowledge and to share mathematical topics with their students.

Although teachers employed common digital technologies when they implemented contemporary teaching approaches, such as inquiry-based and collaborative learning, they found this use challenging, as I described above. The teachers used Dynamic Geometry Environments (DGE) (e.g., GeoGebra) to engage their students in inquiry-based learning. The teachers were asked to prepare and provide their students with appropriate tasks to prompt the inquiry processes. The software and the appropriate tasks are two essential elements for inquiry-based learning to take place, but they are not sufficient. In fact, the commonly used digital technologies do not have a feature that can provide teachers with the information needed for prompting inquiry-based learning. To prompt inquiry-based learning, teachers have to be aware of the students' learning processes in real-time to guide their exploration processes (Lazonder & Harmsen, 2016; Schwarz et al., 2021).

In the same line of thought, prompting collaborative learning and fostering argumentation-based learning is not only an issue of setting the students together to discuss or solve mathematical problems or exercises. On the contrary, teachers have a crucial role in these learning settings. To ensure the evolution of the learning process, they should mediate the daily concepts that may emerge in the students' discourse, guiding them towards the scientific concepts that are culturally accepted among the scientific community (Vygotsky,

2012). Also, teachers should ask open-ended questions to support students in argumentation and encourage dialogic interactions between students (McNeill & Pimentel, 2010). Thus, teachers who wish to advance the collaborative and argumentative learning process must be aware of the students' learning progression and the content of the discourse.

To benefit teachers in remote learning, digital tools must provide the teachers with the information and the data they need. To my knowledge, the ubiquitous digital technologies commonly used during the Covid-19 period did not fully meet this requirement. To fill this lacuna, teachers used video recording to implement teaching methods similar to the flipped classroom approach (Tang, et al., 2020). In doing so, teachers prepared short-duration clips that introduced the concepts to the students. Students were asked to watch the video before the lesson. During the lesson, the teacher interacted and engaged in discussion with the students based on what they watched (Aldon et al., 2020).

To conduct collaborative learning sessions, teachers utilized the breakout room options available in several video conference platforms (e.g., Zoom, MS Teams). The creation of small groups allowed the exchange of ideas between the students. The teachers, who attended the virtual room from time to time, could offer guidance only based on what they observed or heard through their presence in the virtual room. Other teachers asked their students, in groups, to prepare a summary of the lesson and to show and explain their summary during the lesson session (Aldon et al., 2020).

Teachers used several kinds of technologies to support students who face difficulties during their learning process. The most common tool teachers used to support their students was instant messaging technology. For example, teachers used the option in MS Teams to send personalized messages to their students to find out how the exercises were going and to offer them their support. Other teachers used one-to-one communication applications such as WhatsApp or messenger to offer private help to the students. A third group of teachers used video recording to provide explanations targeted to individuals. Some teachers grouped lower-achieving with high-achieving students, hoping the latter would support the former.

Identifying and dealing with the students' emotions was one of the main challenges teachers faced during the Covid-19 period. To overcome these challenges, teachers connected with their students daily via instant messaging tools or emails. Teachers used, for example, WhatsApp recording options to ask about the student's emotions and feelings (Aldon et al., 2020). Some used the chat option, available on the video conference platforms, to ask students individually about their feelings during the lesson. A third group of teachers chose to contact their students directly via phone call if the teacher recognized the need to do so. Although these digital tools are useful for supporting students emotionally, they are limited. These tools allow the teacher to support the student after the lesson is finished or to support students when the teacher recognizes that they need affective help. However, these tools are not useful when teachers want to support several students at the same time or cannot help in supporting students that the teachers do not recognize as somebody needing help.

Regarding the assessment issue, teachers used several platforms and strategies to assess students formatively and summatively. They used platforms that automatically provided grades, or they adopted non-educational software, such as Google forum, to assist them in collecting data and organizing the results. The teachers also implemented several kinds of

strategies to formatively assess their students. Teachers encouraged students to express their ideas explicitly in order to conclude how they understand the topics they have learned. Others asked students to prepare portfolio protocols using shared files, such as google docs. Some of the teachers asked their students to summarise the content they had learned and to present it using PowerPoint presentations.

INNOVATIVE LEARNING SYSTEMS THAT ARE INSPIRED BY THE PANDEMIC

So far, I have briefly reviewed some of the challenges teachers faced during the Covid-19 period, and I reviewed how teachers used digital tools to deal with these challenges. My main argument in this talk is that the challenges that manifested during the Covid-19 period and the ways teachers utilized digital tools to deal with these challenges created unique opportunities for researchers and software designers to develop innovative digital tools, which can help in overcoming some of the challenges and can improve instructional practices after the pandemic. To support my argument, I will discuss three examples of digital tools designed to help teachers deal with these challenges. The first system is called SAGLET: It is a system aimed at fostering inquiry-based Learning through social interaction. The second system in the MathematicX. This system is designed to help teachers in organizing the learning process. It allows teachers to choose a topic they want to teach and to set a generic question. The system will automatically create content similar to the topic that has been chosen. The system will present the content step by step to the students to help them progress at their rate. The third system is Dash4Emotion, which alerts teachers on the students' sentiments in real-time.

SAGLET

SAGLET (Segal et al., 2017) is designed to support collaborative learning and inquiry-based learning using educational software in classrooms. SAGLET (Figure 1) augments existing online learning environments to include technology tools that are capable of (1) recognizing critical moments of emergent learning in groups that interact with one another using educational software and (2) visualizing salient information to teachers. SAGLET provides a set of alerts that the teacher may use in order to handle the orchestration of multiple groups (in up to 12 virtual rooms) engaged concurrently in a learning task. Although the provision of critical moments seems clearly useful, caution is required in using alerts in learning processes.

Segal et al., (2017) integrated SAGLET with VMT software. VMT includes a Geogebra applet shared by all participants so as to provide opportunity for collaboration on geometrical tasks (Stahl, 2013). Figure 1 displays the VMT interface, which is comprised of two parts. First, it includes an inquiry space where small groups of students can share their mathematical explorations and co-construct geometric figures online (part A). When one of the participants drags or constructs a geometrical figure, all the others can see the changes in the figure. As shown in Figure 1, VMT also provides a chat window (part B) in which students can write their ideas and share them with their peers.

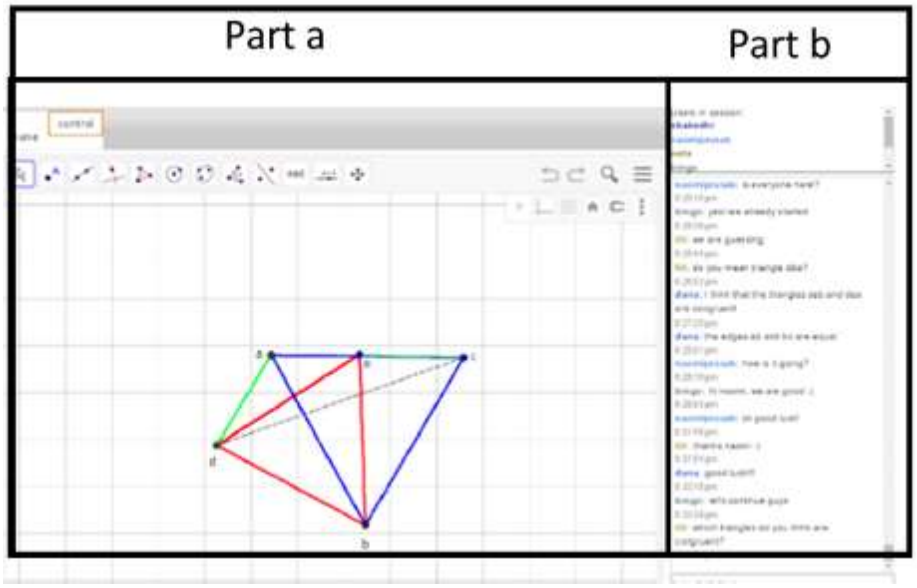

Figure 1: The VMT interface.

SAGLET allows teachers to observe, online, the work of groups of students engaged in learning tasks with VMT in different virtual rooms and to intervene whenever they think it appropriate. As the learners progress in their group work, SAGLET informs the teacher about critical moments through alerts. Figure 2 shows an instance of windows observable by the teacher. In this case, the teacher was informed about an off-topic (blue frame) discussion in virtual room 454 and a technical problem (yellow frame) in virtual room 486. The alerts are easily visible as a colored frame appears according to the alert type. Teachers can ignore alerts or decide to respond by entering any virtual room they wish.

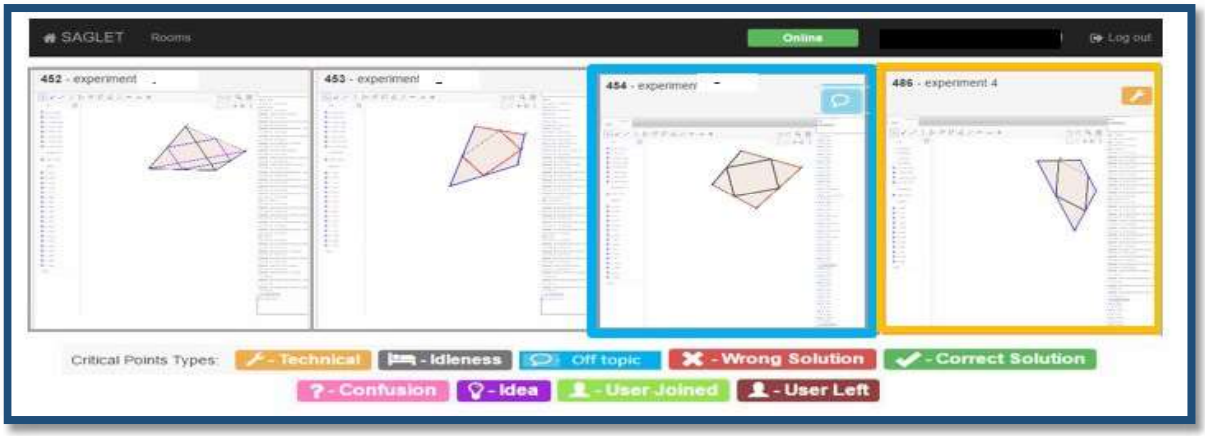

Figure 2**:** The teacher is informed about an off-topic discourse in room 454 and about a technical problem in room 486.

MathamticX

The MathematicX platform (Lisutta, et al. 2023), which is still under development, has two main interfaces. The first interface is for students, and the second is for teachers. In this platform, the teacher constructs the content to be learned. The system assists the teacher in constructing the content and collects data about the students' learning processes. The

MathematicX system provides a list of topics from which teachers can choose. For example, let us assume the teacher wants to teach the students how the 'm' and 'n' parameters affect the linear function graph. In this case, the teacher should choose the topic "linear function." The MathematicX system provides the teacher with several types of functions, such as polynomial, trigonometric, exponential, etc. (Figure 3a). The teacher then chooses a polynomial and determines the degree of the function. In our example case, the teacher chooses the degree of the function as 1. In the next step, the teacher chooses the request that may guide his/her students to learn the intended topic, in our case, the effect of the 'm' and 'n' parameters on the linear function graph. The teacher can choose the request from a set of ready-made requests (Figure 3b). Once the function type and the item's request are determined, the teacher must set the variation domain of the parameters (i.e., the 'm' and 'n' parameters) (Figure 3c).

This design principle was motivated by the variation theory of learning (Marton et al., 2004). Variation theory defines learning as a change in the way an object of learning is discerned: how it is seen, experienced, understood. According to variation theory, an object of learning can be formulated in three different ways of increasing precision, in terms of: content (e.g., a linear function), educational objectives (e.g., generalizing family of linear function), and critical aspects, which the learners should simultaneously discern to make the object of learning their own.

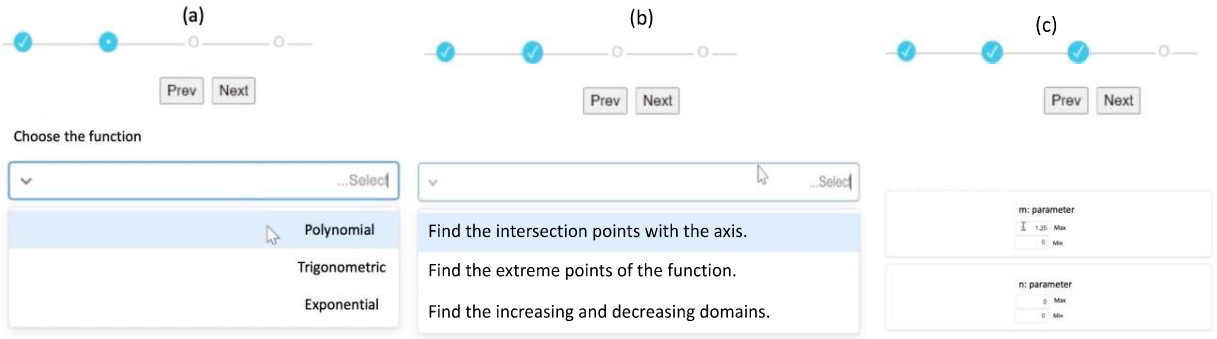

Figure 3: (a) type of function that can be chosen, (b) ready-made request for the items, (c) the interface of setting the value of the parameters.

According to Marton et al. (2004), learning occurs through the separation of the object of learning from other objects from the same dimension of variation, which refers to the aspect to focus on (e.g., varying 'm' while keeping 'n' constant). After discerning the meaning of the variation of one parameter, the whole must be put together again to simultaneously experience certain aspects of the object of learning: this pattern is called fusion. To endow an object of learning with meaning, it should be constrained with other objects (e.g., to identify a function as linear, it should be constrained with functions that are not linear). Once the meaning is found through the contrast pattern, the generalization of the object of learning becomes necessary.

Inspired by the variation theory, the MathematicX system allows the teacher to separate parameters by determining which parameter will vary. It also allows the teacher to constrain one type of function with another, and it allows the teacher to fuse the variation of several parameters at the same time.

Once the teacher has prepared the learning sessions, the system will automatically generate items that meet the principles he/she has set. To move from one learning session to the second, the teacher should decide the number of the requested successful attempts the students are required to make. For example, the teacher can decide that after three successful attempts of the same type of item, the system will move to the second type of item. If the students are not able to solve correctly, the system can give them hints on how to progress. The system also allows the students to chat and send messages to the teacher and the students.

The teacher interface in the MathematicX interface includes a dashboard that contains descriptive statistical analysis per student and class. The system provides, for example, data concerning how many items each student has solved, the distribution of the correct and incorrect attempts, the time the students took to complete the session, and which students completed the entire session, and which did not.

Dash4Emotion

Dash4Emotion platform (Jbareen et al., 2023), which is also still under construction, has a different perspective than SAGLET and MathematicX. Dash4Emotion is an innovative system for monitoring students' emotions (Figure 4) and alerting teachers about their students' emotions in real-time. It is designed to help teachers be aware of the students' emotions while they are learning mathematics in order to allow the teacher to regulate the students' emotions if needed. The Dash4Emotion system uses *AI emotion recognition,* a field of computer vision focusing on facial *emotion detection* and automatic *sentiment* analysis from visual data. Facial *emotion detection* software is a tool that makes it possible to detect and determine displayed human *emotions*.

Figure 4: Set of sentiments that the Dash4Emotion can detect.

To avoid an overload of alerts to be sent to the teacher, the designers decided to inform the teacher about the students' sadness, fear, anger, only if the students maintained this sentiment for more than 10 seconds. Of the surprised sentiment, the system immediately informs the teacher. Of happiness, the teacher is informed only after 60 seconds, and is not informed at all when students are neutral or disgusted.

FINAL REMARKS

My aim in discussing the three systems is to illustrate how the challenges manifested during the Covid-19 period helped in reflecting on developing or looking for digital systems that might overcome some of those challenges. I am not arguing that the learning systems

discussed in this paper are deemed to solve all the challenges created during the Covid-19 period. Nor that the systems we are developing is the best solution for overcoming the challenges.

The SAGLET system, for example, which provides a shared space for inquiry and allows grouping students to foster collaborative learning, can follow the students' learning and inform the teachers on how the students are progressing or even being hindered. SAGLET, by allowing the teachers to be aware of what is going on in the virtual rooms, can help in overcoming challenges related to applying the collaborative learning and contemporary instruction approach, which arose as a result of the remote learning during the COVID-19 period. In addition, the data provided by SAGLET and sent to the teacher can support the teachers in formatively assessing their students. These data can elicit evidence of students' understanding (Cusi et al., 2022). The MathematicX platform, by allowing teachers to create the content they want to teach and by allowing each student to progress at their own rate, can be a solution for supporting students who face difficulties. The Dash4Emotion platform can be considered as a solution for detecting students' emotions, which was one of the main challenges that teachers faced during Covid-19 period.

Although, I hope, the Covid-19 lockdown period is over, it has presented opportunities for raising new ideas on how to design innovative learning environments. I believe that the learning platforms that have recently emerged can influence the educational system in the future. These systems can be used not only during the pandemic period but also during ordinary days. I should note that the three systems briefly presented here are not the only ones available today, nor are they the best. Other systems, designed to overcome other challenges, are also available today (e.g., Asymptote) (Barlovits et al., 2022). This effort, without any doubt, is very blessed. The emergence of such systems requires systematic research to understand how teachers and students use such systems, and how they are able to help them overcome the challenges they meet. As we learned from our research on the SAGLET system, this learning platform solves some issues, but its use in the classrooms also creates new challenges (Schwarz et al., 2021). International collaboration is needed to study how the use of such digital tools may help in overcoming the challenges and what other kinds of challenges the new technologies may create.

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