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Instrumental orchestration during emergency remote mathematics teaching

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The purpose of this study is to identify potentially evolving instrumental orchestration types under the conditions of emergency remote teaching during COVID-19 pandemic. We used a teaching experiment method, which mainly focused on learning processes of a group of pre-service mathematics teachers regarding 3D constructions with GeoGebra. The first author of this paper as a mathematics teacher educator conducted the teaching with 28 pre-service mathematics teachers who had experiences in 2D construction tasks with GeoGebra. We collected data by using the video/voice recording functions of a video conferencing platform, Zoom. We conducted thematic analysis to examine and identify the applied orchestration types by referring to the defined orchestrations in the literature. The findings indicated that each lesson was carried out with Spot-and-show and Sherpa-at-work that had new features with the use of video conferencing tools.

Keywords: Emergency remote mathematics teaching, instrumental orchestration, pre-service mathematics teachers.

Introduction

The COVID-19 pandemic required a big change in education by leading to school closures around the world. Accordingly, the situation posed a challenge particularly for teachers who were faced with the need to consider working in new ways including teaching online and adapting and developing new types of interactions in such an emergency (Drijvers et al., 2021; Kovacs et al., 2021). Mathematics education is one of the domains that is affected by such a change due to its symbolic nature and specific representations. Drijvers et al. (2021) investigated mathematics teachers' first experiences during COVID-19 and their emerging practices in Germany, Netherlands and Flanders. The researchers indicated that mathematics teachers mainly used general technologies (i.e., video conferencing software) in delivering their lessons rather than mathematics-specific technologies (i.e. dynamic mathematics software). This was not surprising considering all the organisational changes and requirements from the teachers during the process.

In this light, during emergency remote teaching (ERT), we (as teacher educators) designed a teaching process with the use of dynamic mathematics software, GeoGebra to orchestrate pre-service mathematics teachers' learning processes with the use of its tools. Our context was construction tasks focusing on 3D geometrical objects with the use of GeoGebra which provided students with various opportunities to support their reasoning and conceptual learning (Uygan & Bozkurt, 2021). In this paper, our particular focus is on instrumental orchestrations evolving with the combination use of Zoom and GeoGebra during the ERT process. Along this direction, the research question guides this study: "What instrumental orchestrations are performed by a teacher

educator to promote pre-service mathematics teachers' learning processes regarding 3D constructions in GeoGebra under the conditions of emergency remote teaching?"

Theoretical framework

The concept of instrumental orchestration is derived from the instrumental approach to mathematics learning with the use of technological tools (Artigue, 2002; Trouche, 2004). An important concept in this approach is instrumental genesis through which artefacts are expected to shape the actions and thinking of the user while being shaped by the user for a specific type of task. To characterise the teacher's role in guiding students' instrumental genesis, Trouche (2004) introduced the metaphor of instrumental orchestration (IO) with respect to students' learning of mathematics with technology. This framework uses three concepts: a didactical configuration, an exploitation mode (characterised by Trouche (2004)) and a didactical performance (added by Drijvers et al., (2010)). A didactical configuration is essentially an arrangement of technological tools in a classroom environment. An exploitation mode is concerned with how teachers plan to take advantage of technology to achieve their lesson aim. A didactical performance emphasises teachers' ad hoc strategies when an unexpected aspect of a mathematical task or a technological tool occurs in classroom teaching regarding the chosen didactic configuration and exploitation mode.

Research on IO (e.g., Drijvers et al., 2010; Tabach, 2013; Trouche, 2004) has provided operational descriptions, based on a combination of data-driven and theory-driven analysis, for several orchestration types relating to particular didactical exploitations (Table 1).

Table 1: Orchestration types defined in the research on instrumental orchestration

Orchestration Type	Didactical Exploitation
Technical-demo (Drijvers et al., 2010)	Teacher demonstrates tool techniques.
Explain-the-screen (Drijvers et al., 2010)	Teacher explains what happens on the screen to the whole class. The explanation involves mathematical content.
Discuss-the-screen (Drijvers et al., 2010)	Teacher creates a whole-class discussion about what happens on the computer screen.
Spot-and-show (Drijvers et al., 2010)	Teacher brings up student work that he/she had identified as relevant for further discussion.
Sherpa-at-work (Trouche, 2004)	A so-called Sherpa student ¹ uses the technology to carry out actions the teacher requests.
Link-screen-and-board (Drijvers et al., 2010)	Teacher connects mathematical representations on the screen to those on the board.
Monitor-and-guide (Tabach, 2013)	Teacher observes the students' work by walking among students or using an electronic system and provides feedback.

In this study, we particularly focused on the adaptation and/or evolution of the IO types defined in the literature, under the conditions of the ERT process.

¹ The term Sherpa refers to the person who guides and who carries the load during expeditions in the Himalaya mountains, and also to diplomats who prepare international conferences (Trouche, 2004, p. 305).

Methods

This study is part of a teaching experiment focusing on the development of pre-service mathematics teachers' instrumentation of 3D GeoGebra tools and learning processes regarding sphere and sections. Teaching experiment is a research method consisting of a sequence of teaching episodes carried out by a researcher-teacher or a teacher making collaboration with researchers whose aims are to experience students' mathematical learning and to test the hypotheses regarding how students' mathematical learning and reasoning progress (Cobb, 2000; Steffe & Thompson, 2000). Steffe (1991) approaches the teaching experiment as a methodology based on radical constructivism, in which mathematical learning processes of individuals are modelled. On the other hand, Cobb (2000) extends the teaching experiment to investigate learning process of a class by considering the social and sociomathematical norms. In addition to these two different approaches, Steffe and Thompson (2000) express that teaching experiment methodology does not offer a standardised way and can be revised by a researcher who approaches it in a different way. In this light, during the ERT, we planned a teaching experiment consisting of three teaching episodes, which focused on the 3D geometry context in which sphere and sections were explored by a group of pre-service mathematics teachers with the use of 3D GeoGebra tools.

For this aim, we prepared two construction tasks for the first teaching episode as (1) bisecting a line segment and (2) finding centre of a circle, while the other episodes included one each task respectively as (3) finding centre of a sphere, (4) investigating how many points uniquely create a sphere. The first author conducted the teaching, while the second author observed the teaching episodes. Each teaching episode was planned in three stages. In the first stage, the teacher reminded students of their previous task solutions through selected lesson video scenes and introduced the next task to the participants. In the second stage the participants separated into different Zoom breakout rooms and started group work in which each group was created by the researchers before the lesson. In the third stage, the teacher gathered all participants in the main room to allow them to present their group solutions and start whole-class discussions. During the group work phase the researcher-teacher switched between the rooms to monitor each group's work and guide them to reason about the construction steps.

This study was conducted during the Spring term in 2021 at a state university in Turkey in which the ERT process was carried on due to the pandemic. The participants of this study were a group of 28 pre-service mathematics teachers enrolled in a 4-year mathematics education programme and at the time they were in their second year. We chose the participants based on the criterion sampling method (Patton, 2002). In our criteria, the participants were supposed to complete a compulsory course including the Euclidean geometry units and an elective course (conducted through the Zoom platform) including 2D geometrical construction tasks in GeoGebra. Due to learning outcomes of the elective course, the participants were considered as experienced with the instrumentation of 2D geometry tools as point, line, circle, special lines (e.g., perpendicular bisector) and transformation tools in various construction tasks (e.g., finding centre of a circle by creating perpendicular lines of the chords). Also, they participated to a pilot study before the teaching experiment and became familiar with the initial use of the cube, pyramid, sphere, section, plane and reflect in plane tools to construct lines perpendicular to xy plane. In their undergraduate education, the participants took

face-to-face lessons only for one term before the COVID-19 pandemic. Also, we must note that some participants' internet connections were not stable and/or some of them had background noise in their house due to the pandemic conditions.

In the study, we collected the data by recording the students' discussions and operations with the use of the share-screen and video/voice recording functions of the Zoom platform. For the group-work processes, each group-work was recorded separately with the help of a group member who was supposed to start and finish the video/voice recording processes. At the end of each teaching episode the group members, who recorded the group-work, shared the data with the teacher through a file storing and sharing platform.

To analyse the data, we watched the lesson videos entirely and took notes regarding critical features of the performed orchestrations considering the teacher's main intention (e.g., explanation about critical solutions on the screen, discussion on the screen, collaborative learning) and included teacher and student roles. We identified our IO types by comparing their features with those addressed in the research on IO by Trouche (2004), Drijvers et al. (2010) and Tabach (2013). Following this, we used a coding frame to identify some IO types whose components mainly coincided with those predefined in the literature. On the other hand, we also inductively created different codes to define other IOs, whose essential components evolved due to the conditions of the ERT process. For instance, when the teacher shared his screen with the students and made mathematical explanations about the operations on his screen, this IO type was named "Explain-the-screen" by referring to Drijvers et al (2010). Additionally, "Switch-monitor-guide" code was used to name a new IO type as an adapted version of the Monitor-and-guide (Tabach, 2013) from physical classroom environment to the ERT process. In the Switch-monitor-guide, the teacher switched between the different breakout rooms involving the group work, monitored the students' operations, listened to their conversation, and then guided them if necessary.

Results

As stated above, the results of this study stem from a teaching experiment aiming at the pre-service mathematics teachers' instrumentation of 3D GeoGebra tools during the ERT process. The teaching experiment was conducted synchronously online through Zoom due to the lockdown requirements during the pandemic. To provide a collaborative learning environment during online lessons, we mainly conducted group-work by separating the participants into different breakout rooms in Zoom. Such a learning arrangement required amendments in some of the identified IOs in the literature (Drijvers et al., 2010; Trouche, 2004). Here, due to the space limitation, we will focus on revision of Sherpa-at-work and Spot-and-show orchestration types. Figure 1 illustrates the orchestration types conducted during the stages (whole-class introductory, group work, whole-class summary) of the teaching processes.

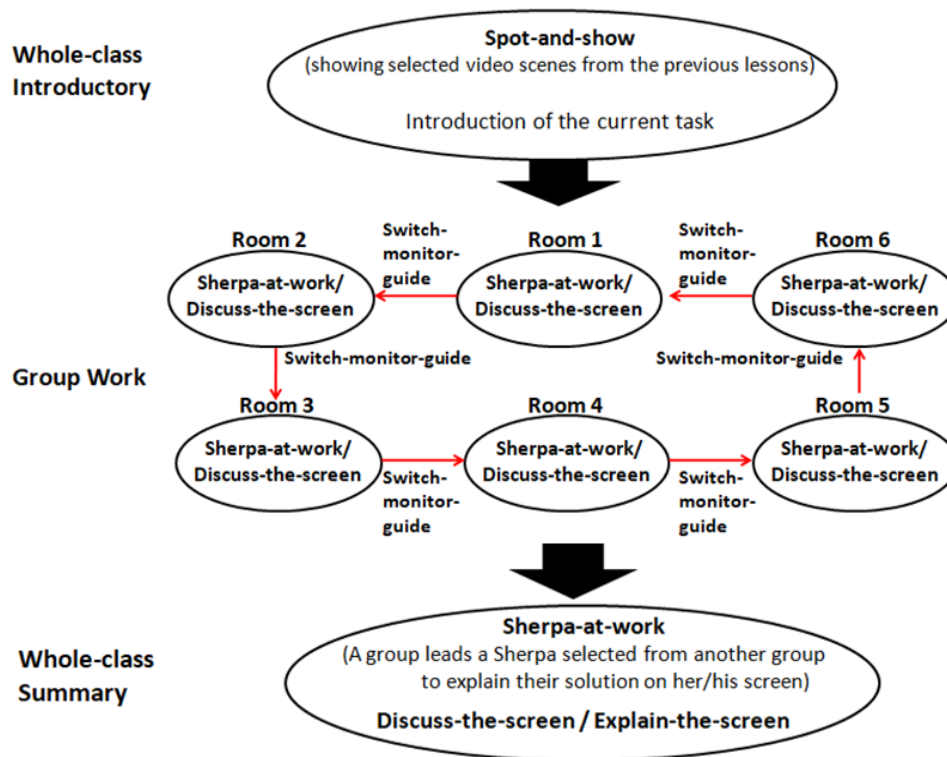


Figure 1: Instrumental orchestrations applied during the teaching processes

The IO type performed by the teacher during the whole-class introductory (at the beginning of the lesson) was identified as a new version of the Spot-and-show. In this orchestration, didactical intention was to examine the previous lesson videos, determine the critical parts including certain groups' task solutions and show these video parts to start the new lesson. By this way, the teacher managed to remind the students of their last work and allow them to construct their following task solutions. Didactical configuration included teacher's access to video records of previous lessons during lesson preparation and share-screen function of the video conferencing platform during online lessons. For the exploitation mode, the teacher determined the critical moments of the previous lessons and organised them in a sequence to make a presentation and prepare the students to make connections between their previous and further work. Then, for the didactical performance, the teacher shared the selected video scenes with the students and asked questions to them to draw their attention to their previous critical moments. The verbatim transcript below shows a part of a dialogue between the teacher and some students that occurred during the Spot-and-show orchestration in which the teacher showed a video scene regarding a group's solution steps to find centre of a given sphere.

Teacher: Do you remember that? You were confused there. You thought as if this (plane) was a plane segment because of its limited appearance (see Figure 2a). But in fact, it represented a plane intersecting that sphere. And this cross-section is a circle. Do you remember what they created by their next operation (showing the next operation on the video [see Figure 2b])?

Fuat: They created a line perpendicular to the plane and passing through the centre of the circle.

- Sibel: So, this operation gave them the diameter of the sphere.
- Teacher: Yes! Let's watch their next step. Barkın, do you remember what you would do in your next step here?
- Barkın: Sure! We made another circle on the sphere by using *the circle with three points* tool.
- Teacher: Right! You would use the intersections of the line and the sphere to make a new circle. And that circle would be one of the largest circles on the sphere.

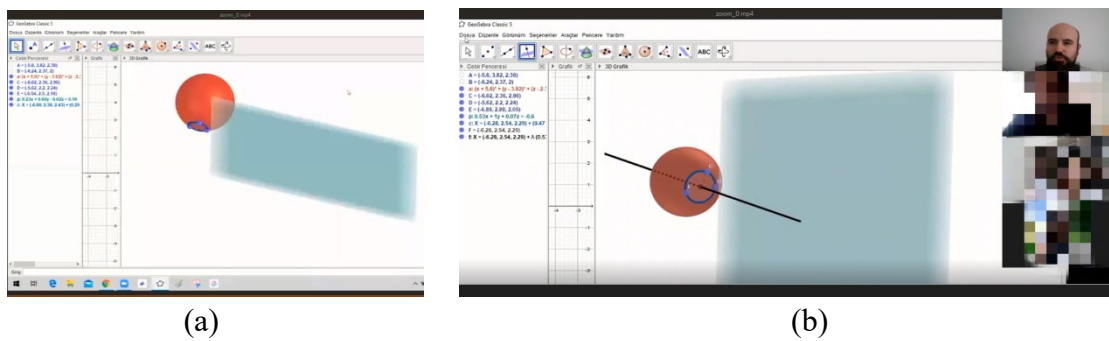


Figure 2: The scenes from the Spot-and-show orchestration

By sharing the solution above, the teacher aimed to highlight the largest circles on the sphere before introducing the next task in which the students would be asked to investigate how many points uniquely create a sphere. The teacher predicted that the students could overlook the properties of the largest circles on the sphere while studying on the next task. More clearly, the teacher thought that the students could come up with the idea that three points would be sufficient to uniquely create a sphere by inferring that the centre of the circle constructed with three points would also be the centre of the sphere. Hence, the teacher allowed them to consider the fact that any circle constructed with three points did not have to be the largest circle on the sphere.

In terms of IO types included in the group work stage, our didactical intention was to support collaborative learning to develop construction strategies that were asked to be performed on a shared screen among students. For this aim, one student selected from each group was given the responsibility to share her/his screen with the other group members. At this point, when these students carried out the operations on the screen following their friends' ideas, we identified the IO type as Sherpa-at-work. Also, if these students presented their own operations and allowed the fellow students to discuss on the screen, we defined the IO type as "Discuss-the-screen". Didactical configuration of both IO types performed in the group work stages included the use of Zoom breakout rooms, its share-screen function, microphone, the annotation, and remote-control tools. Exploitation mode consisted of separating the students into different breakout rooms in which they could work in groups. In addition, each group would have a student sharing her/his screen with the other group members and we would also allow the group members to use the annotation or the remote-control tool to help the student performing her/his operations on the screen. For the first teaching episode, each group was encouraged to carry out their open discussion while developing a strategy, in which the teacher posed spontaneous questions during the Switch-monitor-guide to support students' reasoning. However, we observed that the students mostly tended to perform trial and error methods on the screen. Hence, in the next episodes, we asked each student to first make a

construction plan on her/his own computer with mathematical references before starting the group work. After the group-work stage, the teacher regularly employed the Sherpa-at-work orchestration at the whole-class summary phase. A selected student was asked to use the share-screen function of Zoom and performed the operations requested by the students from different groups. Finally, the teacher started a whole-class discussion or made explanations regarding the students' solutions.

Conclusion

This study indicated that instrumental orchestrations conducted during online teaching have new features with the use of video conferencing tools (Orozco-Santiago et al., 2022). Video/voice recording tools particularly provided opportunities to develop the Spot-and-show orchestration by showing students the critical video scenes selected from the previous lessons. This adapted orchestration type can enable teachers to plan the introduction of the further lessons through which students may have opportunities to remember both their previous mistakes and accurate reasoning.

The results of our study also point out that Sherpa-at-work orchestration defined by Trouche (2004) could be adapted to online teaching in different ways with the use of various functions of video conferencing platform. The group-work and whole class-work phases provided the teacher with two different ways to apply the Sherpa-at-work. In the group-work, each group had a Sherpa student in which the group members developed the solution steps on her/his computer screen. For the whole-class work, a Sherpa student performed the strategies following the ideas by different groups. Before the group work, it was crucial that each student individually prepared a construction plan to enrich the group discussion and solution. Also, during the group work, Switch-monitor-guide orchestration played an important role that enabled the teacher to draw students' attention to critical points on the screen. Our results also revealed that the students' use of the annotation or remote-control tools could help Sherpa students with their operations. However, we must note that most of the students did not prefer to utilise them. Finally, the results of the teaching experiment indicated the evolution of students' instrumentation processes regarding the sphere, plane, section tools and the function of creating 2D views in their 3D constructions.

Following the COVID-19 pandemic, it is of crucial importance for teachers and teacher educators to focus on and elaborate management of teaching methods of online teaching and/or hybrid teaching (Geraniou & Crisan, 2022). Hence, we believe that findings of this paper will contribute to the literature by providing an example of potential instrumental orchestrations for online mathematics teaching.

References

- Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning*, 7(3), 245–274.
<https://doi.org/10.1023/A:1022103903080>
- Cobb, P. (2000). Conducting teaching experiments in collaboration with teachers. In A. Kelly & R. A. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 307–333). Lawrence Erlbaum Associates Inc.

- Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics*, 75(2), 213–234. <https://doi.org/10.1007/s10649-010-9254-5>
- Drijvers, P., Thurm, D., Vandervieren, E., Klinger, M., Moons, F., van der Ree, H., Barzel, B., & Doorman, M. (2021). Distance mathematics teaching in Flanders, Germany, and the Netherlands during COVID-19 lockdown. *Educational Studies in Mathematics*, 108(1-2), 35–64. <https://doi.org/10.1007/s10649-021-10094-5>
- Geraniou, E., & Crisan, C. (2022). Design considerations for facilitating mathematical learning online. In J. Hodgen, E. Geraniou, G. Bolondi, & F. Ferretti (Eds.), *Proceedings of the Twelfth Congress of the European Society for Research in Mathematics Education (CERME12)* (pp. 2733–2740). Free University of Bozen-Bolzano and ERME.
- Kovacs, H., Pulfrey, C., & Monnier, E.-C. (2021). Surviving but not thriving: Comparing primary, vocational and higher education teachers' experiences during the COVID-19 lockdown. *Education and Information Technologies*, 26(6), 7543–7567. <https://doi.org/10.1007/s10639-021-10616-x>
- Orozco-Santiago, J., Cuevas-Vallejo, A., & Trouche, L. (2022). Instrumental orchestrations by a university teacher in an online linear algebra course. In J. Hodgen, E. Geraniou, G. Bolondi, & F. Ferretti (Eds.), *Proceedings of the Twelfth Congress of the European Society for Research in Mathematics Education (CERME12)* (pp. 2801–2808). Free University of Bozen-Bolzano and ERME.
- Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Sage.
- Steffe, L. P. (1991). The constructivist teaching experiment: Illustrations and implications. In E. Von Glasersfeld (Ed.), *Radical constructivism in mathematics education* (pp. 177–194). Kluwer Academic Press.
- Steffe, L. P., & Thompson, P. W. (2000). Teaching experiment methodology: Underlying principles and essential elements. In A. Kelly & R. A. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 266–287). Lawrence Erlbaum Associates Inc.
- Tabach, M. (2013). Developing a general framework for instrumental orchestration. In B. Ubuz, C. Haser, & M. A. Mariotti (Eds.), *Proceedings of the Eighth Congress of the European Society for Research in Mathematics Education (CERME8)* (pp. 2744–2753).
- Trouche, L. (2004). Managing the complexity of human/machine interactions in computerized learning environments: Guiding students' command process through instrumental orchestrations. *International Journal of Computers for Mathematical Learning*, 9(3), 281–307. <https://doi.org/10.1007/s10758-004-3468-5>
- Uygan, C., & Bozkurt, G. (2021). Construction of cyclic quadrilateral: A pre-service teacher's journey from subsets to the generic concept through instrumentation of a dynamic technology. *Journal of Mathematical Behavior*, 63, 100893. <https://doi.org/10.1016/j.jmathb.2021.100893>