INSTRUMENTAL ORCHESTRATIONS USED IN TECHNOLOGY-SUPPORTED TEACHING FOR CLASSIFICATION OF TRIANGLES AND QUADRILATERALS

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Abstract
The use of technology has an essential place in geometry teaching due to its positive effect on learning. However, it is often difficult to decide at what stage and to what extent the technology will be used. The instrumental approach offers researchers/teachers a way to overcome this challenge. The instrumental orchestration within the framework of this approach shows what kind of environment we should create for the instrumental genesis of students. In this study, we aimed to investigate the instrumental orchestrations used in the implementation of technology-supported activities for the classification of triangles and quadrilaterals. The technological tools we used in the study were "Shape Makers" prepared with Geometer's Sketchpad software. In the study carried out with 5th-grade students of a private school, we used six different types of activities related to triangles and quadrilaterals. We analyzed the data obtained in the study by descriptive analysis method. Consequently, we observed that several orchestrations in the literature were used together for each type of activity.

Keywords: Classification of triangles and quadrilaterals, instrumental orchestration, technology-supported teaching.

INTRODUCTION
Geometry has attracted a great deal of attention since the earliest times in history, to overcome problems in daily life and to conduct scientific studies. In research studies in this exciting area, it is emphasized that understanding basic concepts is very important in making progress in the field of geometry (Craine & Rubenstein, 1993; De Villiers, 1994; Driskell, 2004; Goldenberg, Cuoco, & Mark, 2009). According to Heid (1988, p.4), "if mathematics instruction were to concentrate on meaning and concepts first, that initial learning would be processed deeply and remembered well. A stable cognitive structure could be formed on which later skill development could built." Also, being able to establish relationships between geometric concepts and associate them with other fields, and thus to raise individuals who can conduct geometric reasoning is one of the essential goals of education (Ministry of National Education [MoNE], 2018).

Researches in the field of geometry teaching indicate that dynamic geometry software considerably contributes to teaching shapes (Battista, 2001; Erez & Yerushalmy, 2006; Han, 2007; Lai & White, 2012). Olive (2010) emphasizes that it is necessary to understand the effects of methods that focus on how technology is used on learning and teaching outcomes. In other words, knowing how to organize learning environments for tool use is vital to understand the impact of technology on learning. "Technology continues to evolve and rapidly change the everyday world and the classroom,..., it is increasing necessary to understand better how new and emerging digital tools can be used effectively" (Sinclair, Bartolini-Bussi, De Villiers, Jones, Kortenkamp, Leung, & Qwens, 2017, p. 282). In this respect, the theoretical framework used in instructional design is also essential. Olive (2010) stated that the instrumental approach provides an appropriate theoretical framework to analyze how technology is used and how it is shaped. Besides, many researchers working in the classroom environment based on the instrumental approach state that the concept of instrumental
Orchestration is beneficial in the preparation and implementation of learning environments for tool use. (Drijvers, Doorman, Boon, & van Gisbergen, 2010; Tabach, 2013; Trouche, 2003; 2004).

Instrumental orchestration refers to the organization of teachers’ or students’ workspaces and times to analyze the instrumental genesis of students based on tool use (Trouche, 2003; 2004). This approach shows what kind of environment teachers should create for the instrumental genesis of the tools offered to students. Drijvers, Doorman, Boon, Reed, and Gravemeijer (2010) stated that the instrumental orchestration model provides a rich framework for analyzing teachers’ practices while teaching mathematics with technological tools. There are many different types of orchestrations put forward by various researchers in the related literature. The table below gives brief information about these orchestrations in the literature.

Table 1: Instrumental Orchestrations in the Literature

<table>
<thead>
<tr>
<th>Orchestration type</th>
<th>Short description</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical demo</td>
<td>It relates to the demonstration of the techniques of the tool by the teacher.</td>
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</tr>
<tr>
<td>Explain-the-screen</td>
<td>It is about the explanations made to the whole class by the teacher, guided by the things happening on the computer screen. Explanations require mathematical content beyond techniques.</td>
<td>Drijvers, Doorman, Boon, Reed, and Gravemeijer, 2010</td>
</tr>
<tr>
<td>Link-screen-board</td>
<td>Teachers emphasize the relationship between what happens in the technological environment and how to represent it in other settings (such as books or boards).</td>
<td></td>
</tr>
<tr>
<td>Discuss-the-screen</td>
<td>It is all about class discussions about what happens on the computer screen. The goal is to develop collective instrumental genesis.</td>
<td></td>
</tr>
<tr>
<td>Spot-and-show</td>
<td>Student reasoning is brought to the fore through the identification of interesting digital mathematics environment (DME) students work during the preparation of the lesson, and its deliberate use in classroom discussion.</td>
<td></td>
</tr>
<tr>
<td>Sherpa-at-work/ Sherpa-student</td>
<td>Sherpa student uses technology to present his/her work, or to carry out actions the teacher requests.</td>
<td>Tabach, 2011</td>
</tr>
<tr>
<td>Not-use-tech</td>
<td>There is an environment in which the teacher makes instructional explanations by not choosing to use technology.</td>
<td>Drijvers, 2012</td>
</tr>
<tr>
<td>Work-and-walk-by</td>
<td>Students work individually, and the teacher provides answers to questions by walking or sitting with students. In some cases, the teacher can make explanations on the board for a question from the student.</td>
<td></td>
</tr>
<tr>
<td>Discuss-tech-without-it</td>
<td>In the classroom, there is an environment where discussions on technology use are held at the beginning of the lesson. Still, technology is not used during these discussions.</td>
<td></td>
</tr>
<tr>
<td>Monitor-and-guide</td>
<td>In some cases, there is an environment where teachers answer technical questions of the students and explain the operations on the screen, and in some cases, send messages remotely to students who have problems through classroom management software.</td>
<td>Tabach, 2013</td>
</tr>
<tr>
<td>Guide-and-explain</td>
<td>It has similar features to explain-the-screen and discuss-the-screen.</td>
<td>Drijvers, Tacoma, Besamusca, Doorman, and Boon, 2013</td>
</tr>
<tr>
<td>Board-instruction</td>
<td>Despite the technical possibilities in the classroom, the teacher explains the students to the blackboard as in traditional teaching.</td>
<td></td>
</tr>
</tbody>
</table>
In this orchestration, technical issues play a central role. The teacher supports the student in technical problems that go beyond the DME technology, such as login difficulties, software bugs, or hardware issues.  

Kraky, 2016

There is collective management of the instrumental genesis. The class tells the presenter what to do.

Discuss-artifact-use

Students make comparisons between different tools. There is a discussion environment that takes advantage of students' experiences. In this way, a collective instrumental genesis is aimed.

Student-choose-tech

Students have the right to decide and choose which of the different tools to use for a math problem. In this way, they can use strategically appropriate tools.

Talk-without-tech

Students deal with problem-solving without using a tool. Here, there are the collective instrumental genesis and, therefore, class discussions.

Boad-with-tech-reference

It is a type of orchestration in which teaching is carried out directly as in traditional education, and the content is transferred directly to students. It is about expressing, reviewing, and summarizing technical procedures related to tools.

Collaborative problem solving

It is an orchestration where two groups of students are faced with the problem situation and that students work collaboratively and develop solutions.

Uygan, 2016

It is a type of orchestration in which the whole class is asked to complete a geometric construction within the given time, all students in the class are activated in the lesson, it is aimed to develop collaborative work in the class, and the teacher plays a guiding role.

Collective work against time

The teacher encourages students to test and check themselves through dynamic software. In this environment, since the student receives feedback from dynamic software in verifying his / her knowledge, he/she is not dependent on the teacher or other students in controlling his / her predictions. In this orchestration type, which is the student is directly involved with the software, the teacher prepares appropriate tasks to support this interaction and to guide the process.

Bozkurt and Ruthven, 2018

Purpose of the Research

In this study, we aimed to investigate the instrumental orchestrations used in technology-supported teaching for the classification of triangles and quadrilaterals. In this context, we sought an answer to the following research question.
What are the orchestrations used in the implementation process of the activities prepared using the Shape Makers on the classification of triangles and quadrilaterals at the middle school level?

**METHOD**

In this study, as we analyzed the development of the learning process in the classroom in detail, we used the teaching experiment within the scope of the qualitative approach. "The teaching experiment is a conceptual tool that researchers use in the organization of their activities" (Steffe & Thompson, 2000, p. 273). Besides, Czarnocha and Maj (2008) stated that the teaching experiment is a teaching-based experimental tool that allows analyzing the nature of learning mathematics, the development of students' mathematical thinking, and the issues related to interaction with teachers-researchers.

We used the Shape Makers, which are dynamic tools prepared based on Geometer's Sketchpad software, in the design of the activities. We named these six different types of activity designed based on triangles and quadrilaterals as let’s get to know shape makers, can you do that, prediction and control, features of shapes, a new type of triangle, and riddles. These activities were used in a recurring order in accordance with the planned structure in the teaching of shapes.

The classroom environment in which we conducted the research consists of a smartboard, a blackboard, a teacher's desk, and individual desks and cabinets for sixteen students. In the classroom, which we divided into groups of two during the lessons, we gave a laptop to each group. In this classroom environment, all students sat in their chairs, and we combined the group's desk and installed computers belonging to the group in the middle of these tables. In this way, we facilitated for both students to access the computer.

We connected the computer set up on the teacher's desk to the smartboard and made available for use where necessary. The chalkboard in the classroom is in a sliding format that can be enlarged by covering the smartboard when necessary. Before the implementation, we loaded activities used in lessons on each of the groups' computers. To open the relevant activity in each lesson is the duty of the students. The teacher said which activity to choose from which folder for each activity and the students opened the related file and started the activity. We try to preserve this configuration during the lessons, where each student was able to access technology, and the classroom could follow the explanations that could be made on the smartboard.

**Study Group**

This research is carried out with fifth-grade students studying in a private school in Fethiye, Turkey. There were 16 students (eleven girls, five boys) in the fifth grade of the determined school. The students participating in the study worked in groups of two during the lessons. The school where the research is carried out is located in a region with a medium-high level of socio-economic status. We carried out the implementation in the spring semester of the 2018-2019 academic year on the dates covered in the curriculum to avoid disrupting the curriculum. In the selection of the school, we considered the school to have a computer lab and to allow the placement of the mathematics courses in the computer lab on the dates of the implementation. In this respect, the selected sample falls into the criterion sample type from the purposeful sampling method. In criterion sampling, the sample consists of people, events, objects, or situations with the qualifications identified concerning the problem (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz ve Demirel, 2013).

**Data Collection Tools and Data Analysis**

We used a camera that records the whole class to record the data emerging within the lessons. We took this record to analyze both the classroom environment and the communication between the student and the teacher. Also, we used a voice recorder to record class discussions to prevent possible data loss. Also, notes were kept by the researcher after each lesson. The aim here is to support future analysis by recording the points that can be overlooked in the video recording, the researcher's thoughts about the course, the situations that occur during the lessons. Through these
notes, instructional details that need attention and correction in the next lessons were also revealed more clearly.

Findings for instrumental orchestrations used in teaching were analyzed descriptively, considering the relevant conceptual framework (instrumental orchestration) after the video recordings were written and supported by the researcher's notes.

**FINDINGS**

Findings obtained in the study were grouped based on activity types. In the table below, we presented which orchestration types are used in each activity. After the table, we gave sample data on how to decide on the orchestration type.

<table>
<thead>
<tr>
<th>Activity name</th>
<th>Instrumental orchestration used</th>
</tr>
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<tbody>
<tr>
<td>Let's get to know shape makers</td>
<td>Technical demo, technical support, explain-the-screen, work-and-walk-by</td>
</tr>
<tr>
<td>Can you do that</td>
<td>Explain-the-screen, work-and-walk-by, student-choose-tech, collaborative problem solving, technical support, technical demo</td>
</tr>
<tr>
<td>Prediction and control</td>
<td>Predict-and-test, technical demo, technical support, explain-the-screen, work-and-walk-by, collaborative problem solving, discuss-tech-without-it, not-use-tech, board-instruction</td>
</tr>
<tr>
<td>Features of shapes</td>
<td>Technical demo, explain-the-screen, discuss-the-screen, work-and-walk-by, collaborative problem solving, link-screen-board, not-use-tech, discuss-tech-without-it, guide-and-explain, discuss-artifact-use</td>
</tr>
<tr>
<td>A new type of triangle</td>
<td>Collaborative problem solving, technical demo, explain-the-screen, work-and-walk-by, predict-and-test, board-instruction</td>
</tr>
<tr>
<td>Riddles</td>
<td>Not-use-tech, talk-without-tech, board-instruction</td>
</tr>
</tbody>
</table>

In the *Let's Get to Know Shape Makers* activity, the second group did not make sense of the information that came out when they opened the program at first and said to the teacher, "Madam, came out like this." When the teacher came to them, stating, "okay it will go soon," the group turned the information off by clicking a blank space on the screen by chance. Then the teacher went to another group in the same situation, clicked on an empty part of the screen, and turned off the information (technical support orchestration).

In the following section, a student from the fourth group said, "madam, that is to say, can I do with Triangle Maker, four things here (referring to other Makers)?" he asked. When the teacher told him to try and decide, he said, "now I'll take it here," and he moved the Triangle Maker to an empty part of the screen (Figure 1). Realizing that several other groups did the same, the teacher held one of the Makers on the smartboard and moved it to another place. After that, she said, "if you want to move the Maker completely, you click the middle of the Maker and drag it" (technical demo orchestration).
In the Can You Do That activity (Figure 2), students were free to choose which of the Shape Maker to use. Also, students in the group had a chance to exchange ideas during the decision-making process.

An example dialog is given below.

S4: (pointing to Obtuse Triangle Maker) that can do it, with that we can do this (D)
S3: (leaving Isosceles Triangle Maker) walk then, you come baby
...
S4: We use the Isosceles Triangle Maker for shape A
S3: Because we saw it compatible (then she make C with the Triangle Maker) Look, I did something, look
S4: Wow, very nice!
S3: (While trying to make B with Equilateral Triangle Maker) why doesn't it fit, I can't, I will do this
    (she moved Right Triangle Maker to shape E)
S4: (When the S3 left the maker without fitting it to E) it didn't work, give it to me
S3: Take it, I am already tired
S4: (after trying for a while) that maker doesn't fit E because it always has a right angle!

In light of this dialogue, we can say that student-choose-tech and collaborative problem-solving orchestrations are used within the scope of the activity Can You Do That.

In the Prediction & Control activity (rectangle & rhombus) used in the Prediction and Control activity type, the students guessed which of the quadrilaterals given could be made with Rhombus and Rectangle Maker, respectively. And then, they checked their predictions with these makers, respectively. After the students finished their tasks, the teacher distributed the worksheet on which there is the construction she had drawn on the blackboard (Figure 3).

**Square-Rectangle-Rhombus-Parallelogram**

![Figure 3: The construction drawn on the blackboard during the prediction & control activity.](image)

Then the teacher asked the students some questions about their work on their computers. Some examples of these dialogues in the classroom are given below.

**Teacher:** Why cannot the Rectangle Maker make rhombuses?
**S10:** Because, madam, even though the Rectangle Maker meets the condition that all sides are equal, rhombus can be acute-angled or obtuse-angled.
**Teacher:** That's it. Is this everyone heard? Why cannot the Rectangle Maker make rhombuses? Because all the angles of the rectangle have to be 90 degrees, so the Rectangle Maker doesn't let you make a rhombus, so why can't the Rhombus Maker make a rectangle?
**S11:** The rectangle's sides are not even!
**Teacher:** Yes, the Rhombus Maker makes only all sides with equal shapes. Now (pointing to the third structure on the board, Figure 3) you have four quadrilaterals (square, rectangle, rhombus, parallelogram), how should we put them in these boxes? You have to think who could make the other, who was in whose family. You will place these four quadrilaterals here, okay.

When this discussion process that takes place after the completion of the activity is taken into consideration, we can say that in this technology-supported environment, without using smart-board or dynamic tools (the Shape Makers), discuss-tech-without-it and not-use-tech orchestrations are used in this process, which contains essential mathematical content.
In the Features of the Shapes activity, the teacher answered students' questions by navigating through the desks during the activity. For example, while the second group analyzes the properties of the Isosceles Triangle Maker, they have produced an equilateral triangle after dragging the intersection point of two identical sides of the maker for a while. Meanwhile, the length of the third side has always remained constant. The group then asked the teacher for help. When the teacher goes to the group, the dialogue between them is given below.

*S4: Here, we noticed that the lengths of A and B (the side of AB) remain the same all the time, but the thing is, the others can play two but equal.*
*Teacher: Then you say sometimes two sides are equal, sometimes three sides, how can you express this?*
*S4: (after thinking for a while) I don’t know*
*Teacher: For example, if I say at least two sides have to be equal, would it be correct?*
*S4: Ok*

After this dialogue, the group noted at least two equal sides for the isosceles triangle on the worksheet. Afterward, the group analyzing the angles said, "at least two angles are equal to each other" and then made a note on the sheet. We can say that during this process, when the teacher went to the group who asked for help while walking in the classroom, she used the work-and-walk-by orchestration.

In A New Type of Triangle (triangles by the edges) activity, the teacher also showed how to open from the smart board after telling which activity to open. Then, the teacher said, "you should note three triangles which cannot be made with the Equilateral Triangle Maker and the Isosceles Triangle Maker but can be made with the Triangle Maker. For example, look, I made a triangle like this with the Triangle Maker, see the lengths" (Figure 4), and pointed to the triangle 3, 4, 5 cm, which she made with the Triangle Maker on the smartboard.

![Figure 4: A new triangle type activity smart board image.](image)

After that, the teacher stated that she could not make this triangle since all the triangles made by the Equilateral Triangle Maker should be equal. When she asked, "can I make this triangle with the Isosceles Triangle Maker?" the class said "no," and S12 tried to explain the reason by saying, "two sides must be equal." The teacher then released the students to analyze, saying, "yes, I want you to find the triangles like that." At this stage, the teacher explaining what happened on the screen in connection with the mathematical content shows that explain-the-screen orchestration is used.

In the Riddles activity, after the teacher distributes the worksheets, she said, "there is a riddle on each page of the activity papers, you read that riddle and find out which the Maker is the answer. You should consider Square, the Rectangle, and Parallelogram Maker in these three riddles, and which riddle's answer is which you will find, okay, got it?". Then, S2 said, "the answer of a riddle is either the Square Maker or the Rectangle Maker." The teacher said, "yes, after writing your answer, mark the following quadrilaterals that can be made by the Maker of your choice" and showed the relevant part from the worksheet simultaneously. In the meantime, the video image showing the classroom
environment is given in Figure 5.

![Figure 5: A screenshot from riddles activity video recording.](image)

In this type of activity that does not require the use of technology in a technology-supported environment, the process where the teacher explains the activity shows that the not-use-tech orchestration is used.

**DISCUSSION AND CONCLUSION**

In this study, we investigated the orchestrations used in the implementation process of the activities prepared using shape makers. In this context, we analyzed teaching in the fifth grade within the framework of instrumental orchestration.

This study showed that in the process that uses more than one type of activity in each lesson, the teacher used a combination of many different types of orchestration. This result is in line with the results of Tabach (2013). Tabach (2013), who observed 30 math teachers teaching different levels in his study, stated that some teachers used many kinds of orchestrations together (for example, explain-the-screen, discuss-the-screen, technical demo, link-screen-board).

Another result of this study was that the orchestrations used by the teacher follow a particular order in the *Let’s Get to Know Shape Makers* activity, which is one of the activities used. This type of activity used twice, both in triangles and rectangles. The teacher used technical demo, technical support, explain-the-screen, work-and-walk-by orchestrations, respectively, for each time. In other types of activities, we can say that a similar order is followed in itself. This result is similar to the results of Tabach (2013) and Drijvers Doorman, Boon, Reed, and Gravemeijer (2010). In both studies, it was stated that the orchestration types used by some teachers in the classes had a similar order.

This study revealed that the teacher mostly uses the *work-and-walk-by orchestration* in the implementation of each type of activity prepared for a different purpose. It can be said that this situation is related to the view of the teacher about learning. Drijvers, Doorman, Boon, Reed, and Gravemeijer (2010) concluded that there is a connection between the types of orchestration used by teachers and their opinions about teaching. However, since this issue is not within the focus of our research, it is thought that it can be analyzed in future studies.

**Note 1:** This study was presented as an oral presentation at 11th International Congress on New Trends in Education, April 18, 2020, Turkey.
Note 2: The data provided here is driven from the doctoral thesis of the first author supervised by the second author at Bursa Uludağ University.

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