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► To cite this version:

Johanna Zöchbauer, Markus Hohenwarter, Zsolt Lavicza. Improving the GeoGebra Classroom tool to better accommodate online educational resource development based on the SAMR model. Twelfth Congress of the European Society for Research in Mathematics Education (CERME12), Feb 2022, Bozen-Bolzano, Italy. ⟨hal-03753514⟩

HAL Id: hal-03753514

<https://hal.science/hal-03753514v1>

Submitted on 18 Aug 2022

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Improving the GeoGebra Classroom tool to better accommodate online educational resource development based on the SAMR model

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This paper describes an exploratory case study within a project aiming to develop a novel connected classroom technology (CCT) for offering new possibilities for teaching with technologies. It outlines a lesson in which three-dimensional coordinates were taught through an online resource created based on the SAMR (Substitution, Augmentation, Modification, Redefinition) model and the GeoGebra Classroom tool. Moreover, this paper presents findings of our study focusing on the interconnections of tangible and digital tools as well as on tasks that offer whole-class activities and student interactions. Findings of our study indicate that creating online resources based on the SAMR model, collaborative work between developers of tools and task designers could be valuable. In addition, when creating online resources offering advanced teaching possibilities, developers of these tools and task designers must collaborate and interact with teachers who are using them.

Keywords: Class Activities, connected classroom technology, digital tools, tangible tools, educational resources.

Introduction

This research project aims to develop a new, mathematically suited, tool offering novel opportunities for mathematics teaching to support teachers as well as to assist students' learning. Our objective is to develop a tool that allows a variety of possible applications in teaching and supporting learning. The idea is to use powerful mathematics software and further develop an existing online tool into a connected classroom technology (CCT) by implementing new features and functionalities (see Zöchbauer & Hohenwarter, 2020; Zöchbauer et al., 2021). The technology, in this case, is GeoGebra Classroom, an online tool for teachers' and students' devices that are connected online and can be used for teachers and students to interact with each other. GeoGebra Classroom can be used for interactive teaching approaches in various settings and can be applied to all levels of education. Moreover, we have great opportunities to work with developers to adapt this tool based on our research findings.

“Connected classroom technology refers to a networked system of personal computers or handheld devices specifically designed to be used in a classroom for interactive teaching and learning” (Irving, 2006, p. 16). This technology offers a broad range of innovative features such as facilitating communication between teachers and students, displaying student responses in real-time, and allowing rapid aggregation of student work by teachers (Irving, 2006; Shirley et al., 2011; Wright et al., 2018). Furthermore, CCT enables most students to contribute directly to interactive activities and to play a more active role in classroom discussions (Shirley et al., 2011; Wright et al., 2018). GeoGebra Classroom could be also used in the classroom for formative assessment enabling teachers to utilize a wide variety of teaching methods. According to the Organisation for Economic Co-operation and Development OECD (2005), “formative assessment refers to frequent, interactive

assessments of student progress and understanding. Teachers are then able to adjust teaching approaches to better meet identified learning needs” (OECD, 2005, p. 13).

Within this project, we conduct studies in various STEM lessons for evaluating potential uses of GeoGebra Classroom for mathematics teaching and learning. This paper describes our most recent research, where the first author was using tangible and digital tools in a lesson by conducting an exploratory case study with a mixed-methods approach. Moreover, the first author created online resources that offer a unique experience thanks to new technology. For creating such online resources the SAMR (Substitution, Augmentation, Modification, Redefinition) model of Puentedura (2006) was used.

Regarding the combination of tangible and digital tools for the learning and teaching of mathematics, there has been a growing interest, which is also due to a slow evolution of teachers’ practices in integrating digital tools in mathematics teaching (Soury-Lavergne, 2021). Nemirovsky and Sinclair (2020) “distinguish digital tools as being computer-screen centred and tangible tools as being for holding, grabbing, and manual transport” (Nemirovsky & Sinclair, 2020, p. 107). By using digital tools as well as tangible tools there is a high potential for bodily engagement (Nemirovsky & Sinclair, 2020).

In this case study, the first author used online resources with GeoGebra Classroom as the digital tool (see Figure 2) and some Dick System Maths Cubes together with a handmade 3D coordinate system (see Figure 1) as tangible tools. For working with the digital resource, all students used an iPad.

This case study is part of a larger project, where the GeoGebra Classroom tool is evaluated with mixed methods, where we utilized the combination of educational research with usability and user experience methodologies. In this case study, we focus on the usage of the online resource, which is adapted according to the SAMR model. Moreover, we explore the potential of GeoGebra Classroom for whole-class activities and collaboration as well as for group discussions. This case study shows an intermediate step in the development of the online tool and how to improve it. Consequently, the research question for this case study is: How can the GeoGebra Classroom tool be improved to better accommodate online educational resources developed based on the SAMR model?

Theoretical Framework

For creating online resources, we looked at different models and chose Puentedura's SAMR model (Puentedura, 2006). This model provides a tool for integrating digital media into the classroom. Moreover, it describes how teaching and learning are transformed using technology and explains how the design and processing of tasks in the classroom can be improved (bildung.digital, 2021). The four technological levels of use of the SAMR model are *Substitution*, *Augmentation*, *Modification*, and *Redefinition*.

At the lowest level, *Substitution*, there is only a transfer of analog worksheets to digital worksheets happening without functional improvement. An enhancement or a simple functional improvement of the tasks happens in the second level, *Augmentation*. The first two levels are considered *Enhancement* steps, whereas a *Transformation* takes place in the last two levels. In level *Modification*, the tasks will be rephrased in a way, so that digital support is essential for solving the tasks and where the

advantages of the technology will be made explicit. In the top-level *Redefinition*, the tasks will be created in a way that solving them without technology is not possible (bildung.digital, 2021; Puentedura, 2006).

Setting and Task Design

The case study involved a class of 7th-grade secondary school students (age 12-13), learning about the coordinates in a 3D cartesian coordinate system. We have chosen this group of students as they used GeoGebra Classroom and GeoGebra resources before and therefore we do not have to focus on learning the system but could focus on the usage. In a classroom setting, all students received the Dick System Maths Cubes together with a handmade 3D coordinate system (see Figure 1) as tangible tools and an iPad for working with the digital resource (see Figure 2). The students received the devices at the beginning of the lesson from the school equipment. In the class, 21 students participated in the lesson, but only two-thirds of them filled in the questionnaires afterward.

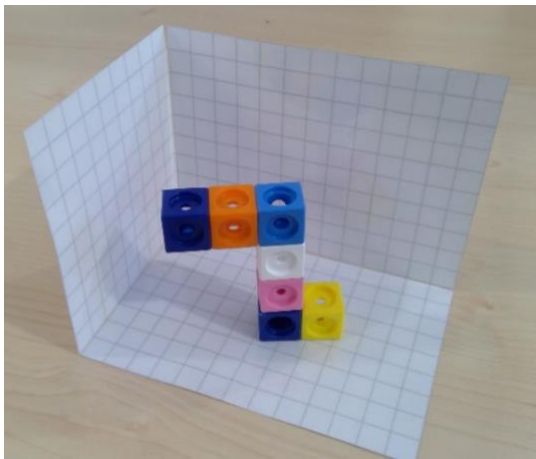


Figure 1: Dick System Maths Cubes

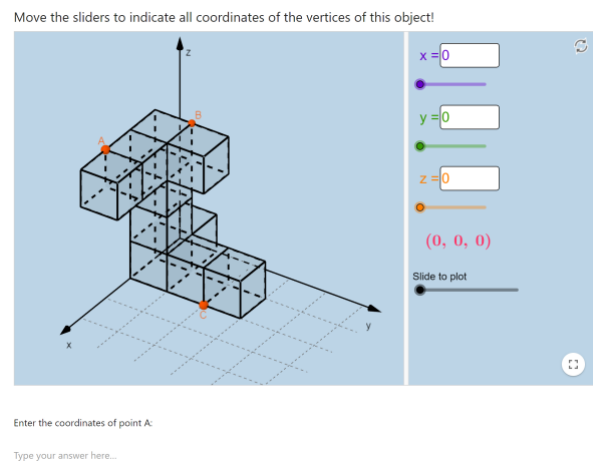


Figure 2: Online Resource

The resource was created by the first author, and the tasks were formulated according to the SAMR model. When creating the tasks, we tried to follow the steps of the SAMR model until we reached the top-level *Redefinition*. For the students, the resource was created in German, a translation can be found here: <https://www.geogebra.org/m/tuzwbwez>.

Firstly, texts were inserted into the online resource as they would have been on a paper and pencil worksheet (level *Substitution*). Secondly, questions were inserted in the online resource as multiple-choice questions (MCQ) or open questions (level *Augmentation*). Then, the 3D object was not inserted as an image, but as an object in the GeoGebra 3D applet, where additional features are possible. Students can move or rotate the object so that they can observe it from different perspectives. Moreover, some sliders are added, where students can move them to show and move a point in the coordinate system (level *Modification*).

As *Redefinition*, a whole-class activity was inserted as the last activity in the online resource. For this activity, the teacher collected all responses of students reasonably quickly and used them for further questions. As a first task, students entered coordinates of a point that was located a) inside the object, b) outside the object, or c) on the surface of the object. Afterward, the teacher selects one of the answers, reads it aloud and the other students had to choose where this point was located by selecting

the correct answer of the MCQ. Before the teacher was choosing another example, all students selected “New”. This activity is considered a redefinition because, within seconds, the teacher can select random students’ examples and observe students’ responses to these new tasks by using the MCQ feature. This way the teacher generates a lot of new tasks and can assess students’ understanding quickly and conveniently.

Methods

To answer the research question, we have selected an exploratory case study. In a case study, a temporary phenomenon is being investigated in-depth and in a specific real-world context (Yin, 2014). In this research, the first author used the current version of the GeoGebra Classroom tool together with some tangible tools in a lesson sequence and collected different kinds of data. A mixed-methods approach was used, and qualitative and quantitative data were analyzed with different instruments.

The whole lesson sequence was video- and audio-recorded with cameras and the teacher’s device was screen recorded. Moreover, we automatically collected student products in GeoGebra Classroom and additionally the teacher’s reflective notes that were made after the lesson. After the lesson sequence, students received an online questionnaire, which consisted of some information about the students, a German translation of the System Usability Scale (SUS) by Brooke (1996), some open questions about their experience with GeoGebra Classroom, and the German version of the User Experience Questionnaire (UEQ) by Laugwitz et al. (2008). The SUS is a simple usability scale giving a global view of subjective assessments of usability (Brooke, 1996), whereas the main goal of the UEQ is a fast and direct measurement of user experience (Laugwitz et al., 2008).

In this case study, the Content Structuring Analysis (Mayring, 2014, 2020) was used, where, as a first step, the categories were defined. According to Mayring (2020), the qualitative content analysis approach is category-based, where the categories refer to aspects within the text and the content analysis procedure is research question oriented. Therefore, concerning the research question, we defined the categories regarding the four technological levels of use: *Substitution*, *Augmentation*, *Modification*, and *Redefinition*. Content structuring in particular means to “filter out from the material specific content dimensions and to summarize this material for each content dimension” (Mayring, 2014, p. 104), and this was accomplished in the next step. Then, we extracted all coded material for each category and summarized it according to Mayring (2014). In each category, all issues are considered, where the usage of GeoGebra Classroom with the resource did not work as expected or where obstacles or interruptions happened during the lesson. Moreover, we collected all issues, where an improvement, either from the teacher or the online resource could be made.

Results

In the first category (1) *Substitution*, all issues are summarized that are referring to the transfer of analog worksheets to online resources only. In the beginning, students needed some minutes to access the online resource and asked three times in total for the link, although it was presented with the QR code on the projector screen above the board in the classroom. Even if the teacher saves time for printing and copying the worksheets in advance, during the lesson, it took nearly five minutes of the 30 minutes lesson sequence to hand out all the other things like iPad, cubes, and coordinate systems.

One thing that was mentioned by students in the questionnaire three times and also seven times during the lesson, was that there were some lags during the lesson caused by the usage of the GeoGebra Classroom tool. Additionally, in the recorded video and teachers' reflective notes, it was shown that not all students used tangible tools for solving the given tasks. Some of them only worked with digital tools and not with tangible ones.

Category (2) *Augmentation* summarizes all issues, where a functional improvement was visible. The teacher could observe in real-time all responses of the students and check several times on the dashboard if the students finished the task on the online resource before discussing it. But during the work with the MCQ, some issues occurred. When discussing the results of the MCQ, the teacher never knew if all students answered this question when opening the chart with all students' responses. Although the teacher could observe in real-time all changes of the selected answers, and see which one has selected which option, there was no information if every student had already answered the question. In the first attempt, the teacher counts all numbers that were shown, but if one student selected two possible solutions, then this method did not work. One thing that worked well was that the teacher showed the different notations of the coordinates (see Figure 3) and explained to them the correct mathematical notation of coordinates.

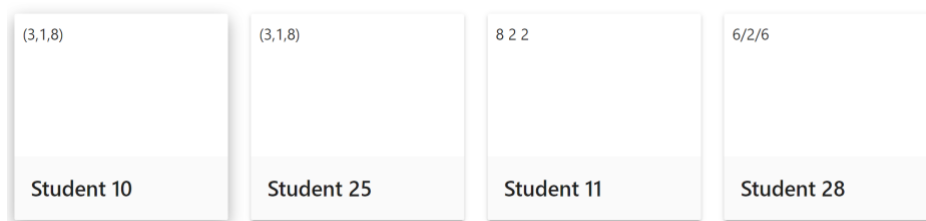


Figure 3: Example of Student Responses regarding Coordinates Notation

All issues regarding the inserted GeoGebra 3D applet (tasks with a significant redesign) are collected in the category (3) *Modification*. The online resource that was used in this lesson, was initially created to be used on a computer with the mouse, but, during the lesson, the students worked with iPads. Therefore, additional hints of using the GeoGebra 3D applet without a mouse would have been helpful. For example, in some cases, the object rotated all the time and students did not know how to stop it. The teacher was interrupted several times to help the kids with this problem. Another issue that occurred was that students could accidentally drag some of the cubes' edges in the 3D applet and therefore change the object dramatically. It was not possible to reset the object to the original one, as the reset button was not available for the 3D view, and refreshing the page did not help either. In this case, these students had to leave GeoGebra Classroom and the online resource and rejoin as new users. Although their work was saved on the teacher dashboard, the students could not access their previous work anymore.

The last category (4) *Redefinition* shows all issues regarding the whole-class activity, a previously inconceivable task. Nevertheless, for the work with the whole-class activity, where several rounds were played, the teacher requested in the reflective notes to just reset all the MCQ solutions instead of choosing the fourth answer "NEW" and to get a notification, when or if all students answered the MCQ. Because during this short whole-class activity it always took some time, until all students

switched from their answer to “NEW” to start with the new example. Moreover, during orchestrating the discussion, the teacher was interrupted two times to help students with technical issues.

The results of the SUS and UEQ will be compared within this project and evaluated in the next phase of the project. Furthermore, the analysis of the relation between the SUS and UEQ data, and the qualitative lesson observation is still in progress and will be presented later.

Discussion

Sinclair and Robutti (2020) describe that the use of digital technology has the two main functions supporting organizing students' work and supporting new ways of doing and representing mathematics. In our study, it was shown that the GeoGebra Classroom tool has the potential to be seen as supporting both functions, whereas in both cases an improvement is necessary.

This case study aimed at investigating how the GeoGebra Classroom tool can be used for online education resources based on the SAMR model of Puentedura (2006). As it was presented in the results section, there are currently several issues that need to be addressed. To answer the research question, we came up with ample amounts of suggestions on how the GeoGebra Classroom tool can be improved to better accommodate online educational resources developed with the SAMR model.

First, sharing the resource with the students should be made easier and faster. The lags which were also mentioned in the questionnaire by the students should be fixed. Nevertheless, it is not clear whether this problem is caused by the GeoGebra Classroom tool itself, the WI-FI connection in the school, or the devices that the students used.

As it was mentioned by Shirley et al. (2011) and Wright et al. (2018), students play a more active role in classroom discussions and the technology enables most students to contribute directly to these interactive activities, such phenomena were also shown during the lesson. Students worked with the online resource and participated actively in the last activity, the whole-class activity. However, when working with the MCQ, it would be great to have an overview of how many students just answered an MCQ instead of always going back to the overview page or counting them. If this was made possible, the teacher could foster students to play even a more active role in the whole-class activity and could easily assess students' understanding quickly. Moreover, a reset button for the MCQ would be helpful when asking a lot of similar questions with the same answer options. Furthermore, in some cases, the option to only allow one possible choice of the MCQ would be helpful.

Besides, there occurred even more issues during the lesson sequence, that are not due to the new tool, but to the creation of the online resource. Thus, before further evaluating the tool, the online resource needs to be enhanced as well. Regarding the 3D applet, editors must always ascertain that all objects are fixed and cannot be dragged by students accidentally. Moreover, a reset button for every view in the GeoGebra applet should be inserted or activated. Furthermore, teachers need to tell students in advance how various features work, such as the rotating feature, and how the students can stop the rotation. Therefore, maybe some additional hints of using the 3D applet would have been helpful for the students and to avoid interruptions. Hence, it was shown that the *Transformation* levels *Modification* and *Redefinition* were not completely fulfilled in this online resource. Some students could not benefit from the 3D object, as there occurred several problems and therefore the 3D applet

with the sliders was useless and the resource did not reach the *Modification* level. To have an online resource, where all stages of the SAMR model are fulfilled, the resource and the system need to be further developed. Moreover, teachers as well need some guidance to work with similar classroom activity tasks.

Additionally, if teachers want students to work with a combination of digital and tangible tools, they should make that connection clearer. Only handing out tangible tools and just giving oral tasks is not enough. Teachers could present this assignment as the first task on the online resources to advise them to build the given object by themselves or verbally repeat this several times and check again if really all students use these tangible tools. Another idea could be to use the *Pause* button of GeoGebra Classroom to interrupt the work of students. When activating the *Pause* feature, students cannot continue working on their tasks and the teacher can get the students' attention and give them important information or additional explanations.

This case study is part of a bigger project and the results of the SUS and UEQ will be compared within this project and evaluated. Once the tool is further developed, the research will be repeated with another case study in a similar setting, but with an enhanced tool and online resource. As the preliminary findings already show, the user experience of the tool is also dependent on the creation and the design of the tasks in online resources.

To sum up, tasks designers, developers, and teachers should be aware of several issues related to educational online resources that are in the *Transformation* level as well as in the *Enhancement* level of the SAMR model of Puentedura (2006). As we can learn from this case study, when creating online resources according to the SAMR model, there are more collaborators than the teacher involved. To have online resources that could offer new possibilities of teaching, developers of new tools and task designers need to work together and with the help of teachers, who are in the classrooms every day and can observe and confirm if the developments are successful.

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