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Encouraging Students' Involvement in Technology-Supported Mathematics Lesson Sequences

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Abstract: This article aims to report on a pilot study with experienced Hungarian teachers who introduced mathematical concepts through a sequence of lessons utilising a pedagogical framework Lavicza et al., [e.g., 1, 2] for general technology integration. In this paper our aim was to focus on the students' experience of the shift in the classroom dynamic and examine how students felt about the teacher's demonstrations and about the student-led activities. Results of this study suggested that students were generally enthusiastic about the use of technology in the classroom, but beyond classroom demonstrations they preferred hands-on activities and opportunities to discuss learning with their peers.

Keywords: Technology-Supported, Mathematics Lessons, STEM Education, GeoGebra, GEOMATECH, Digital Worksheets

1. Introduction

It has been suggested that previous research on students' learning of mathematical ideas and structures, when using mathematics learning technologies, has not caused substantial changes in classroom practices [3]. Meanwhile, there is increasing consensus among mathematics educators that technology is becoming an integral part of mathematics teaching and learning. Amongst the predominant factors that contribute to the deficiency in classroom practices, is "the underdeveloped knowledge of how teachers' practices are impacted by the use of technologies, and subsequently how teachers embed them within their professional lives, for the purpose of improving pupils' mathematical learning" (See [3], p. 1). Recently, research on mathematics teacher education has particularly intensified concentration on identifying the knowledge necessary for the use of technologies [e.g., 4, 5, 6] and the development of teachers' knowledge and practices within technology enhanced classroom environments [e.g, 7, 8, 9, 10, 11]. Additional attention has been directed to the role of mathematics teacher within both mathematics classrooms and during teacher education activities, where the digital technology is shaping the pedagogical and communication tools.

In this paper, we had the opportunity to observe teachers' integration of technology into their classes as part of a pilot program in the GEOMATECH project, an EU-Funded national project aiming to introduce technology into Hungarian classrooms and develop technology resources for the entire curriculum for the Hungarian Education system from year 1 to 12 in most topics in mathematics and physics together with a range of pedagogical approaches. We worked with two participating Hungarian teachers, observing their classes and conducting interviews with them and their students.

While educators widely agree that there is much potential value in integrating technology into classroom practices so students can experience its potential as a powerful learning tool [12], it is also widely agreed that there are concerns for the implementation [13 , 6].

Results from the study of these two cases aim to assist the pilot study of the GEOMATECH project as well as the material and professional development parts of the project. Reports of further studies will describe the implementation of the theories with a wider choice of teachers.

2. Pedagogical Framework

Lavicza et al. [1, 2, 14] observed that most teachers initially used technology as a demonstration tool. When teachers became more familiar with the technology in the classroom, they allowed students to interact more directly with the software. This shift of technology use also resulted changes in

the role of teachers in the classroom. By allowing students to use the software, their role slowly changed from the transmitter of knowledge to a kind of facilitator of the class. Certainly, these changes were not identical for each teacher and the time of transition took different periods of time, but in general this kind of transition occurred in the practices of most teachers who participated in the project for a year. Furthermore, it was apparent that changes required additional preparation time to be able to act as facilitators in the classroom and pre-developed resources for all three kinds of activities were appreciated by the teachers.

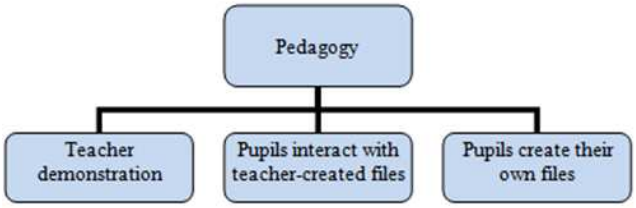

Figure 1. *Pedagogical approaches with GeoGebra (see [1], [2]).*

Having in mind the critical importance of appropriate pedagogical approaches in technology-enhanced teaching environments, they discovered and then further developed and used the framework for teachers' process of technology integration (Figure 1).

The theoretical model proposed by Lavicza et al. [1, 2, 14] involves three phases. In the first phase, the teachers demonstrate new techniques in anticipation of the content material that will follow. In the second phase, the classroom setting is favourably arranged for promoting discussions of students' work on teacher-created files. As exploitation modes, teachers may take student work as a point of departure for the explanation, or start with their own solution for a task. The teachers' may use different exploitation modes that may consider students' work as a starting point or a point of departure for a problem or task that they wish to engage their students with. In the third phase, students create their own files and teachers may select different exploitation modes, such as having a group of students show their work and discuss the main ideas embedded in their work with other students.

In this pilot project, we had an opportunity to observe this framework in action in classrooms, and also to work with experienced teachers to see that this framework could also work for developing teaching sequences to introduce mathematical concepts.

This paper reports on two cases from the GEOMATECH pilot where we tested our theoretical approach. One of the major concerns of the present pilot study was to explore issues related to the transfer of control described by Lavicza et al. [1, 2, 14]. In implementing an educational program on the large scale, teacher practices is crucial. If our intent is to have students more engaged through their use of the technology, then there is a significant concern about how and how quickly teachers can move through the three phases described by Lavicza et al. [1, 2, 14]. In another paper [15], we have examined issues related to the teachers' issues in allowing the students to take more control over classroom activities, as described in [1, 2, 14] model. In that paper, we focused on the teachers' experience and issues that arose as they tried to implement that transition in their classes. In this paper, we now look at that transition from the perspective of the students.

In the previous paper [15], we mentioned how the students reported an appreciation of the pedagogy, their engagement with the material, and their thoughts on how the technology affected their learning. In this paper, we follow up on those basic claims with a tighter focus on the students' experience of the shift in the classroom dynamic—we examine how students felt about the teacher demonstrations and about the student-led activities.

3. Methodology

This section describes the research setting, the research tools and the data collection methods. Finally, the data analysis methods are described.

3.1. Participants

In selecting a purposive sample of participants for this research, several factors were taken into consideration: (a) the number of participants, (b) their expertise; and (c) the variety of schools/school types. School type does not influence the concerns discussed in this paper, however, and will not be considered further.

We observed two teachers who taught 9th grade classes in "average" secondary schools in Budapest, Hungary. (We will use the pseudonyms Brian and Gabriel for the participating teachers from now on.) Both teachers had been interested in computers since childhood and were experienced GeoGebra users. They had extensive knowledge and research experience using technology in classrooms, as they had participated in an earlier research project that documented the modes of methodology working with technology adopted by pre-service and beginning teachers and investigated personal and contextual factors that shaped their pedagogical identities. As teachers, they incorporated digital technologies into their lessons to foster learning of mathematics with technology and facilitated technology-enriched, mathematical experiences that encouraged students to interact more directly with the software to observe the shift of technology use. Additionally, the participating teachers shared a common desire to improve the field of mathematics education.

3.2. Procedure

For this project, we asked the two teachers to select digital worksheets developed within the GEOMATECH project. The chosen digital worksheets should have been suitable for the content they taught in their classes, so these digital worksheets could be implemented into the curriculum and the two teachers' teaching sequences. In this reported research study, teachers selected sets of dynamic mathematics worksheets, the so called GeoGebra worksheets, and implemented them in a

series of classes that we observed and recorded.

We interviewed teachers and discussed the lesson sequences over the study period. The teachers reported that their technology integration was similar to the lesson sequences described by Lavicza et al. [1, 2, 14]. The two teachers became more aware and conscious of their teaching during the lessons. As described in Lavicza et al. [1, 2, 14], during our observations of the lesson sequences, the two teachers first used GeoGebra-based activities and GeoGebra worksheets projected to the whole class under the guidance of, and subject to checking and questioning by, the teacher. The teachers generally led the class discussion by controlling the technology and leading the class. Then they moved towards more student-led activities and allowed increased involvement of students in the lessons.

After each session lasting approximately 1 h each, we interviewed the teachers and invited them to reflect on the session and discuss their plans for the upcoming sessions. In addition, we conducted group unstructured interviews with students in each class about their experiences with the technology-enhanced lessons, their learning, and their expectations and wishes. These interviews offered us further insight into the view of students and we could better understand the results of teachers' intentions on students. Interviewing students added diversity to our data.

The observations and interviews were led by the researchers' experiences of qualitative methods and related literature (e.g. [16], [17]). Each class was videotaped and the interviews were audio recorded, ensuring anonymity and following the ethical considerations of BERA (see [18]). We obtained permissions from each participating student, the parents of each participating student, the two teachers, and the principal of the school. The teachers emphasized the purpose and the presence of researchers in every class.

3.3. Data Analysis

The teaching sessions and the interviews with the teachers and the students, totaling 4 h and 45 minutes of video and recordings, were transcribed. The videotapes of the teaching sessions in the classrooms were fully transcribed, summarised, and important parts of them were selected. These parts were then further reviewed and analysed in terms of the teachers' process of technology integration, students' role during this process and how this process contributed to their learning.

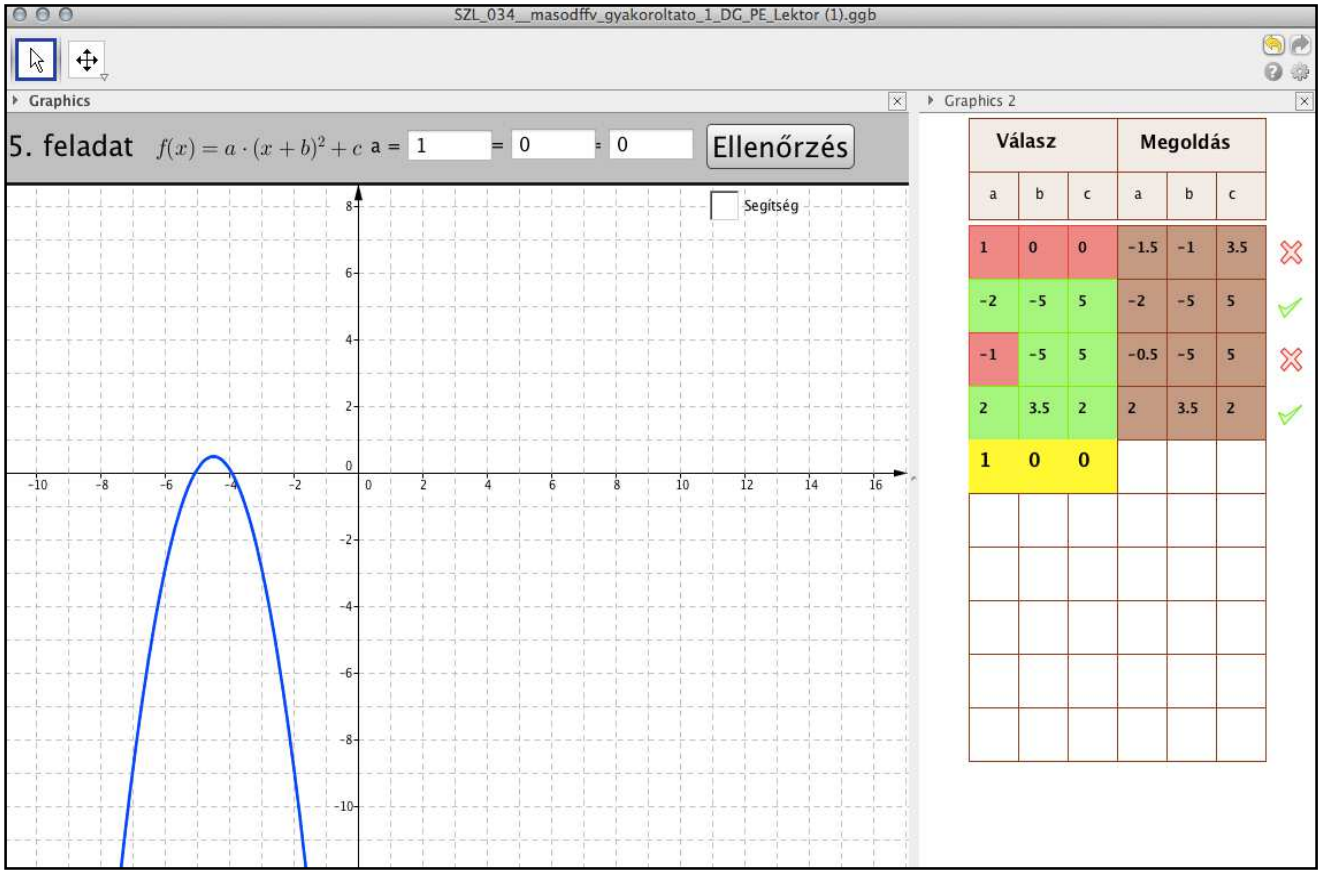

Figure 2. *Some functions in Brian's worksheet.*

Parts of the audio recordings from the interviews with the teachers and the students were also transcribed, analysed at the macro-level to identify common themes or common elements of reasoning. The transcripts were coded, following constant comparative approaches [19]. In particular, the analysis of all data was done by: (a) reviewing similarities that were observed when there was a transfer of control from the teacher to the students, and (b) identifying categories of

focusing issues emerged. We analysed and coded the transcribed interviews, identifying critical events.

Concerning the categories of focusing issues emerged; data analysis followed the interpretative techniques introduced by [19]. We created analytic categories of focusing issues emerged, coded the transcripts from the interviews and searched for instances in the video-recording of the teaching sessions in classroom to cross-validate the identifying categories, and interprete the categorical critical episodes by constantly using a comparative method [20, 21].

4. Results

In the data analysis of students' responses, we aimed to examine how students' views were developed over the lesson sequence, while the teacher allowed students to actively engage with technology to investigate mathematical ideas. First, the teacher only use a projector to demonstrate the concepts of mathematics transformation that were embedded in the GeoGebra worksheet, but later he allowed students to increasingly engage with the worksheet.

4.1. The Case of Brian: Students' Reactions When Brian Demonstrated Concepts of Function Transformation

During the first classes, when the teacher demonstrated concepts of function transformation students clearly observed the benefits of using computers in the classroom (Figure 2,

Brian utilised a worksheet that allowed students to check whether the chosen constants of function transformations were correct or false):

John: These stuff (the GeoGebra applet) really helped me to understand transformations and I think it's a course that is far faster and really very helpful because we are drawing it with the help of the software on the board and it is more precise. [Brian's student, demonstration classes]

In addition, already at the demonstration stage, some students believed that their engagement with technology and their exploration of the behaviour of the use of technology makes the learning of function transformation easier to be comprehended through the immediate visualisation of the impact of constants on functions:

Tom: It is very easy to find a, b, c and if you know what these three do. You know that b moves it left and right and c moved it up and down and so on. [Brian's student, Demonstration classes]

However, teacher's demonstrations were not always sufficient to understand concepts:

Tim: When the teacher demonstrated concepts of functions, and their transformations, I was not sure that I understood how the input constants were related to the quadratic function. [Brian's student, Demonstration classes]

Some students needed further guidance for understanding the connections between the concepts and the demonstrated visuals:

Tim: I felt that I needed to have more guidance, so I asked the teachers to explain again the concepts. [Brian's student, Demonstration classes]

These responses from students already suggested the movement to the next stage, allowing students to engage more with the worksheets. Students' engagement could add to their understanding of mathematical concepts as suggested by Lavicza et al. [1, 2, 14]. Students highlighted that allowing time for student discussions, offered additional opportunity for better understanding of the concepts during the presentation period:

Tim: When I discussed possible answers with other students and checked the results with the software […] my peers offered possible solutions for the problems trying to help me to better understand the concepts. [Brian's student, Demonstration classes]

This was further explained by Tom:

Tom: The fundamental mathematical concepts are important for their lesson and by using GeoGebra students can see the fundamental mathematical ideas immediately in these graphs. […] I prefer to discuss my conclusions with another student and not the group of my classmates and try to explain to each other how we understand the concepts. [Brian's student, Demonstration classes]

4.2. The Case of Gabriel: Students' Reactions When Gabriel Demonstrated Concepts of Function Transformation

Gabriel used similar materials as Brian, but instead of asking students to type in the appropriate constants, he used sliders that allowed the changes of functions to become more visual (Figure 3). However, Gabriel's students reported similar ideas as Brian's students:

Clara: Technology helped me to simultaneously observe the effects of parameters on the graphs of quadratic equations without in fact having to draw the actual graphical representation. [Gabriel's student, Demonstration classes]

Students appreciated the use of technology as a demonstration tool, but hinted that getting more involved in experimentations and exploration would helped them even more. Students' responses during the demonstration classes, were in line with Lavicza et al. [1, 2, 14] teacher model and prepared the ground for students' experiences with the hands on activities. During the classes in which students were asked to experiment with the worksheets, they felt that their learning was further enhanced and reinforced:

Clara: When I asked to experiment with the sliders (Figure 3) that represented the constants for appropriate quadratic function, I found it more helpful because I was able to explore the impact of adjusting the sliders of the constants on the graph of the quadratic function. I like to explore and continuously change the constant and observe the changes in their transformation. This interaction helped me to learn better the concepts and develop this understanding on my own. [Gabriel's student, Exploration classes]

During the demonstration sessions students used the same

or some similar worksheets to explore function transformations. As seen in the earlier quotes, students were happy about the involvement of technology, but when they had a chance to manipulate worksheets by themselves, their satisfaction was increased. We observed that students were paying attention during all classes, but when they had hands on with the worksheets their engagement and attention was increased. Certainly, we will need to further examine these findings in the extended study of the GEOMATECH project, but this small pilot helped us to focus our attention.

Another student further explained his engagement with the technology and elaborated on his learning of concepts:

John: It is really good to work with such software and explore the impact of adjusting the sliders that represent the constants for function transformation and the changes of the shapes of the functions and then reflect on these changes and try to generalise connections between the constants and the behaviour of the graphical transformation. [Gabriel's student, Exploration classes]

During the experimentation, some students believed that they can learn mathematical concepts directly from the software rather than knowing it from previous explanations. It was interesting to see that during the interviews about the demonstration phase, students hinted their better understanding of concepts, but demanded more explanation from the teacher while they reported self-learning from the worksheets directly:

Lucy: I believed that it does not really matter if you do not know the mathematical fundamental ideas, because the visual explanations that GeoGebra offers support students to conceptually understand the basic concepts and even experiment with the functions and the sliders on their own. [Lucy, Gabriel's student, Exploration classes]

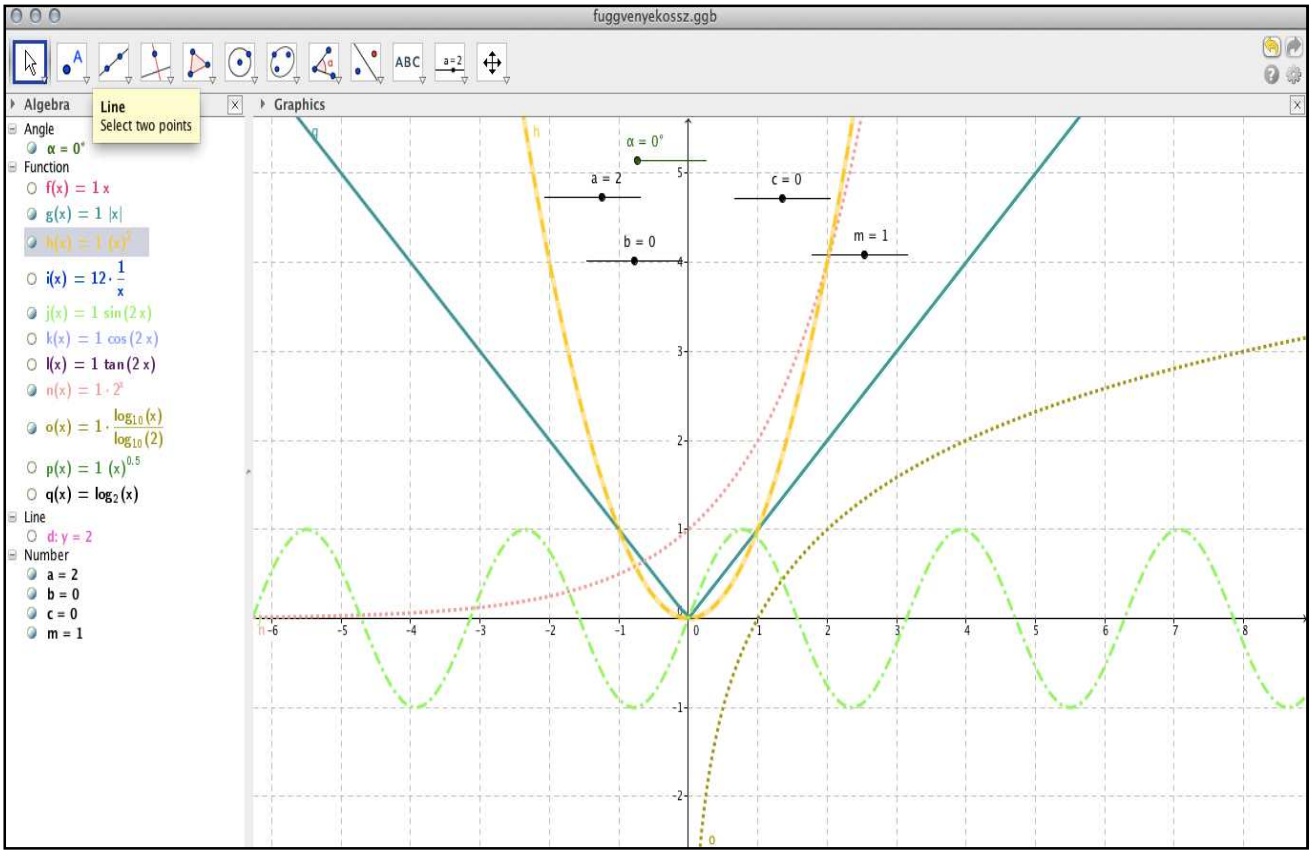

Figure 3. *Some functions in Gabriel's worksheet.*

During students' interaction and exploration with teacher-created files (GeoGebra worksheets), students were more involved in discussion and collaboration. This exploration phase was perceived to be more motivating, enhancing students' learning:

Mary: If you are experienced how to use this program and […] it encourages you to do it at home and do your homework. I like it because you can use it on your own without the help of your mathematics teacher. [Mary, Brian's student, Exploration class]

Students commented that if someone becomes experienced in using GeoGebra worksheets during their mathematics classroom, after experimenting with the appropriate constant parameters, their learning of a particular content will be more motivating and satisfactory. They described that the software supported them to see "how graphs are taking action". They found that this affordance of the software provided them with opportunities to test their set of conjectures, and put forward further experimentation with the animated concepts; providing them with visual representations that can be used as

feedback) when reflecting on a variety of function transformation; following cycles of experimentation and construction of mathematical concepts about function transformation. These are fundamental factors of making the process of mathematics learning independent, and enjoyable. These findings are again in line with our hypothesis that transition from purely demonstrating concepts could have a positive effect on students learning. Nevertheless, combining such a transition with students' direct engagement with the projected material or the GeoGebra worksheets made available in their personal computers at home, could further their understandings. It must be also stressed that the transition has a substantial demand on teachers' preparation and skills required for the delivery of such classes during which opportunities for students' exploration are provided.

5. Discussions and Conclusions

In this small pilot, we hypothesised that introducing a topic by sequencing from demonstrations to students' working with the software, is a resourceful method for meaningful technology integration. However, we have observed that even experienced teachers with advanced knowledge of how to use GeoGebra and integrate technology into mathematics teaching, have some cautions and difficulties to transfer the control of the classroom to students and step back to become a facilitator in the classroom (further explained in [15]).

Students, in general, appreciated the introduction of technology through teacher's demonstration, but they required further explanations from the teacher and opportunities to discuss concepts with their peers. When teachers allowed students to explore worksheets, they were already familiar with the use of the software and this familiarity permitted students' more thoughtful experimentations with the GeoGebra worksheets for learning key mathematical concepts. After the experimentations, students believed that their learning was more successful and they were encouraged to use the software further and also explore it at home.

In sum, our approach seems to be a fruitful approach for integrating technology into experienced teachers' classrooms and could offer valuable resources for teachers who start integrating technology into their current teaching practices. Furthermore, it could offer valuable insights into how students adopt technology integration in their mathematical learning, the way they feel about teacher demonstrations and the student-led activities. However, we continued exploring this idea in the GEOMATECH pilot with 45 teachers and their students and integrated findings into the material and teacher training resources developed for the GEOMATECH project.

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