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# The effect of GeoGebra collaborative and iterative professional development on in-service secondary mathematics teachers' practices

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*Integrating technology in education is still not an easy task, teachers' adoption of technology in their teaching is even more problematic and the wide availability of technology made things more challenging. This research is a multiple case study that aims to study in depth the effect of a GeoGebra (a free mathematics software) intervention on the teaching of in-service mathematics teachers in secondary schools who follow the Lebanese curriculum. The type of the study is Design-Based Research that focuses on working closely with practitioners in collaborative and iterative manner in the real context to add principles to theory and practice. Results showed an increase in the extent teachers use GeoGebra in their student-centered teaching approach.*

*Keywords: Technology integration, professional development, in-service secondary teachers, GeoGebra, design based research.*

## Introduction

When new technologies appear in medical or industrial fields, there is often a rush to replace obsolete tools with new ones, the staff get immediate training on their use and the adoption level is high and quick. Why does this not happen in the education field? Answering this question is not an easy task due to the multiple factors are involved in adopting technology and the rate of change in the education field, which is known to be slow.

## Literature review

Research has extensively focused on the problem of technology integration in general and in mathematics in particular. First, research in many countries has shown that technology still plays a marginal role in mathematics classrooms and that access to technology resources, educational policies, and institutional support are insufficient conditions for ensuring an effective integration of technology into teachers' everyday practices (e.g., Cox, Abbott, Webb, Blakely, Beauchamp, & Rhodes, 2004; Cuban, Kirkpatrick, & Peck, 2001; Goos & Bennison, 2008). Second, research studies in general focused on some aspects of the integration problem such as lack of teachers training (e.g., Law, 2008; Tondeur et al., 2008) or lack of theory (Mishra & Koehler, 2006). Others suggested certain solution(s) such as conducting professional development of specific characteristics, working with mentors (Kratcoski, Swan, Mazzer, 2007), working in a community-based inquiry environment (Lavicza, Hohenwarter, Jones, Lu, & Dawes, 2010), or working based on a theoretical framework such as TPACK, but most of these suggestions "have crashed on the hard rocks of the classroom" (Herrington, McKenney, Reeves, & Oliver, 2007, p. 9). Third, in most studies the methodology used is not sufficient for such a complicated multi-faceted problem, and this partially explains why research has had limited impact on practices (Herrington, McKenney, Reeves, & Oliver, 2007). A key factor is that teachers should be able to actively participate in the process of technology integration (Voogt et al., 2011). To summarise, this research aims to study how a collaborative and

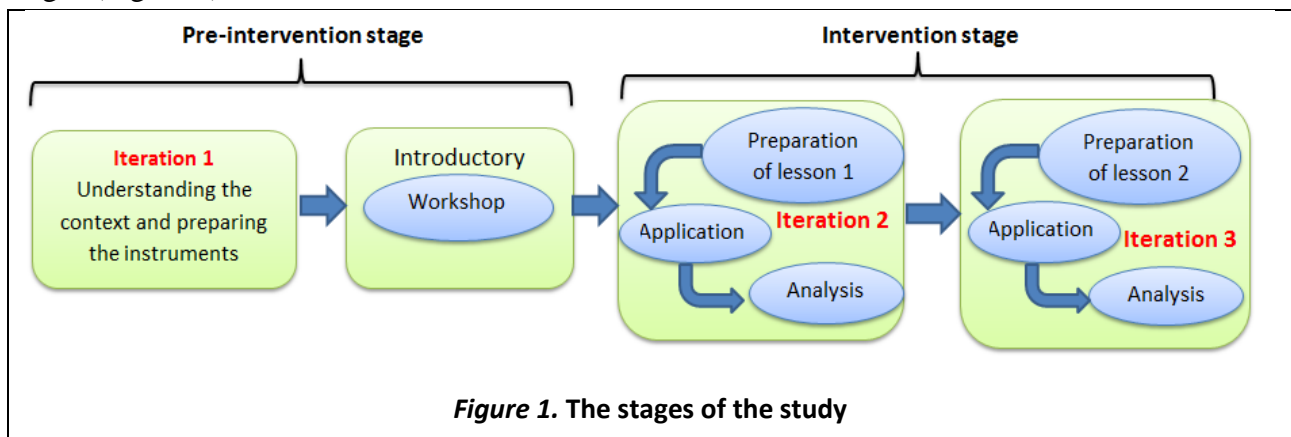
iterative work with in-service mathematics teachers affects their level of GeoGebra integration in their teaching to answer the following research questions:

1. How does a cooperative and iterative intervention affect in-service secondary mathematics teachers' practices regarding the integration of GeoGebra in their teaching?
2. How do participants' Valsiner's three zones mediate the impact of the intervention on teachers' practices regarding the integration of GeoGebra in their teaching?

In this study we have used the Valsiner's zone theory, which states that the factors that affect teachers' use of technology can be categorized into three zones: (1) Zone of proximal development (ZPD) which includes skill, experience, and general pedagogical beliefs; (2) Zone of free movement (ZFM) which includes access to hardware support, curriculum and assessment requirements, students (3) Zone of promoted action (ZPA) which includes pre-service education, practicum courses and professional development (Goos et al., 2010).

## Methodology

Three iterations of a design based research (DBR) methodology were used in this study across two stages (Figure 1).



**Figure 1. The stages of the study**

The first pre-intervention stage was dedicated to understanding the situation of integrating GeoGebra in the Lebanese curriculum, piloting the GeoGebra activities and testing the instruments. Six workshops were conducted over two years and a pilot study with two teachers. At the end of this stage four teachers (other than the ones in the pilot study) were selected as cases for the study. After selecting the participants, a 3 hour-workshop was conducted by the researcher with the four participants to ensure that all participants had acquired the basic features of the software (GeoGebra). In addition, we discussed as a group the topics in the secondary mathematics Lebanese curriculum that could be better taught with the use of GeoGebra. The second stage was the intervention stage, which comprised two iterations. In this stage collaboration was one-to-one between the researcher and each of the participants. In the first iteration, the participating teachers decided which lesson they wanted to teach with GeoGebra in accordance with their school mathematics scope and sequence. They were provided with a ready-made GeoGebra activities (made by the researcher) to be implemented in their classes. In the second iteration, teachers adapted already made GeoGebra activities and/or made their own GeoGebra activities. Three visits were conducted with each participant at his/her own school and according to his/her available time. The first visit was to prepare for the first lesson. The second visit was to evaluate the first lesson and prepare for the second lesson.

Analysis of data collected from the instruments was done before starting the second iteration as required by a design based research methodology. The last visit was to evaluate the second lesson and give a general overview of the whole experience.

### Instruments

For the pre-intervention phase, three questionnaires were administered by the participating teachers: (1) Demographics questionnaire, (2) Instructional Practices in GeoGebra Questionnaire IPGQ (Form 1), (3) Barriers (grouped in zones) in Using Technology Questionnaire BUTQ (Form 1). The purpose of these questionnaires was to measure teachers' current (before the intervention) integration practices of the GeoGebra software in their teaching and the barriers (grouped in three zones) that affect their technology integration. After conducting the first lesson, a semi-structured interview parallel form was used (IPGSI (Form 2) and BUTSI (Form 2) to measure the impact of the intervention on teachers' practices and to find out to what extent the zones could mediate that effect. In addition, another instrument was used to assess the GeoGebra activity itself, the Lesson Assessment Criteria semi-structured Interview (LACI), which is based on instrument by Harris, Grandgenett & Hofer (2010).

The analysis was done in general for the four participants and later individually. The general analysis looked for the general impact of the intervention and for the dynamicity of change in the extent of use in each category of the practices and its subcategories. For the impact of the intervention we were interested in the change in the extent of use of GeoGebra at the end of implementation, whereas for the dynamicity we were interested in the pattern in the extent of use of GeoGebra of change happened in between the implementation stages. The dynamicity could be: (1) static: there was no change in extent of use in between the implementation stages or (2) dynamic: there was a change in extent of use in between the implementation stages.

### Participants

In the sixth (last) workshop conducted by the researcher attendees were given the pre-intervention questionnaires mentioned above. Based on the answers, for the practice instrument, the values were 0 (never use GeoGebra), 1 (sometimes use GeoGebra), and 2 (most of the time use GeoGebra). The average of all the questions was calculated. Similarly the average for each zone was calculated in the zone questionnaire that consists of 27 questions. Based on these results, four cases were selected (Pseudonyms: Tima, Sara, Amani, and Hazem) in a way that they differ among themselves in practice level and/ or in at least one barrier level. Table 1 represents the characteristics of each participant.

Name	Age	Highest degree	Teaching experience	Practice level	ZFM	ZPA	ZPD
Amani	50-55	BS	25 years	Low	Moderate	Moderate	Low
Tima	23-26	Masters +TD	2 years	Moderate	Low	Moderate	Not*
Sara	33-40	BS	7 years	Moderate	Moderate	Low	Not
Hazem	41-50	Masters	31 years	High	Moderate	Not	Not

*Table 1. Participants demographics, practice and zones level*

*\*Not: the zone is not considered as a barrier to GeoGebra integration*

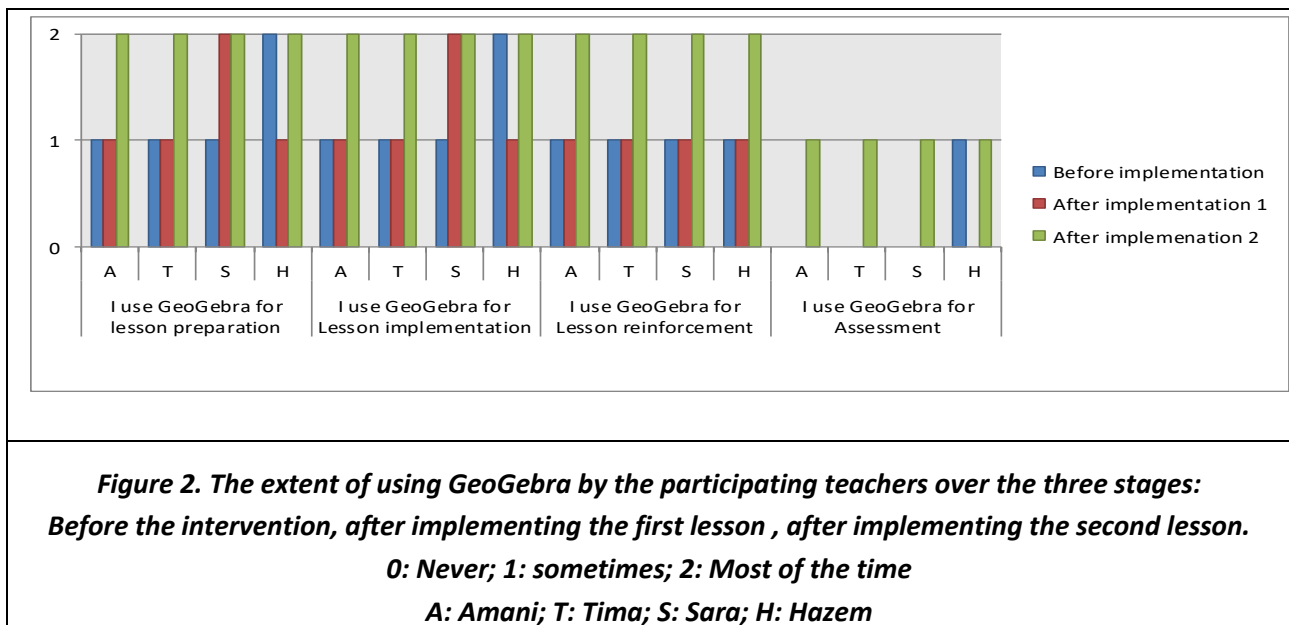
### GeoGebra modules

The criteria used for lesson selection are based on those identified by Angeli & Valanides (2009) called ICT-TPCK. The GeoGebra activities were prepared by the researcher and tested on both students and teachers. The activities were designed based on the following criteria: Each activity: 1) should be student centered, 2) can be conducted by students in a computer lab or elsewhere (classroom or at home), 3) allows student to discover the concept or theorem under study, 4) includes immediate application of the concept under study, 5) does not require prior knowledge of the software.

Each teacher selected an activity according to his/her scope and sequence, so each teacher applied a different GeoGebra activity. Table 2 shows type and place of activities applied by each teacher.

	Activity 1	Place	Activity 2	Place
Amani	Sign of quadratic polynomials	In class	Derivative	In lab
Tima	Vectors	In lab	3D	In class
Hazem	Equation of a straight line	In class	Thales Theorem	In class
Sara	Translation of functions	In lab	Vectors	In lab

**Table 2. The intervention activities conducted by participating teachers**



## Results

### Stage of Use of GeoGebra

Figure 2 shows that the pattern of impact was the same for using GeoGebra in *lesson presentation*, *lesson implementation*, and *lesson enhancement* but different for *assessment*. For *lesson presentation*, *implementation*, and *enhancement*, in general, participants started with ‘sometimes use GeoGebra’ and ended with ‘most of the time’ after the second lesson. For assessment, there was a slight breakthrough from ‘never use of Geogebra in assessment’ to ‘sometimes use’ for each of the four

participants. For all the stages of using GeoGebra, in general, the change was static then dynamic. Probably more time was needed for the change to happen prior to the second implementation, which was due to teachers' need to: become more confident in using the software; be more knowledgeable; and have more free movement.

Concerning the stage of teachers' use of GeoGebra the intervention resulted in: (a) an increase in using GeoGebra in most stages mediated positively by teachers' ZPD, and (b) an increase in teachers' appreciation of GeoGebra as a teaching tool due to the characteristics of the activities. There was interdependence between confidence and the extent of using GeoGebra in each stage. When teachers applied the activities, this led in an increase in teachers' confidence which in turn led to an increase in the extent of GeoGebra use in each of their teaching stages. There was a low impact on using GeoGebra in assessment mediated by teachers' ZFM. Three particular ZFM factors mediated negatively the impact of the intervention on assessment, these factors were: (a) *Lebanese national curriculum* which is so demanding with little time left for discovery, (b) *Lebanese national assessment policies* which assess mostly procedural knowledge, and (c) *school assessment policies* which are mainly set by the school administration and teachers have little impact on changing them. The characteristics of the GeoGebra activities that made impact of the intervention more effective were: (a) the effectiveness of the GeoGebra activity, (b) the ease of operating the software by students, (c) the strong alignment between the activity and the curriculum, and (d) lastly the strong fit of the activity with the instructional strategies each teacher uses.

### **Method of use**

It is important to use GeoGebra, but what is more important is how to use it. In this category of practices the intervention had, in general, *no* to a slight increase in the extent of use in most subcategories and the general pattern of change was static with minimum dynamicity. For example the intervention did not affect Amani's use of GeoGebra for '*presenting a lesson*' or for '*conducting an activity with the help of students*'. Amani used for the first time GeoGebra for '*discovery activity done by students*' or for '*students to present their work*' but that change was static (never use) then dynamic. The impact of the intervention on Amani's *method of use* was a change in her teaching method to become more student-centered (*activity done with the help of students*) mediated positively by her ZFM and her ZPD. A second example is Tima, despite her ZFM factors that mediated Tima's extent of use of GeoGebra in her methods of teaching she applied for the first, time discovery activities done by students in the computer lab and/or in class. The collaboration between Tima and the researcher increased her self-confidence, skills and knowledge and that mediated positively her GeoGebra application. A third example is Sara. Before the intervention Sara was a moderate user of technology in general, and GeoGebra specifically, but the *lack of a computer lab* in her school and the *lack of hardware* in her class were the main barriers to increase technology integration. Sara used to show her students some applets using her class LCD connected to her own laptop but for the first activity she made a huge effort to take her students to the computer lab to apply discovery activities and she said:

After this experience (applying GeoGebra activity) for the first time and in a lab I will change a lot of things (in my teaching) now I have a lab for secondary. Frankly I will not use that with an LCD in the class to show students such things, there is nothing called to show (not effective)

showing them is like treating them as babies not capable of applying and concluding results, when they do it, it is different even for me I felt different. (Interview 2, November 7, 2015).

The intervention had an important effect on increasing the use of *conducting discovery activities done by students* in the computer lab and that change was not the same dynamicity for all teachers. The barriers teachers faced in this part of the practices were the *accessibility to the computer lab* and *curriculum requirements* (ZFM) but these barriers minimally mediated the impact of the intervention.

### Place of use

Similar to *method of use* category there was *no* to slight effect of the intervention on the extent of use of GeoGebra in their classroom or at home. There was a noticeable impact on the use of GeoGebra in the computer lab since three out of the four teachers tried one or both of the GeoGebra intervention lessons for the first time in the computer lab. This was not a surprise because to use GeoGebra in class or in the computer lab is related to availability of equipment and the way of using GeoGebra. This change was not the same dynamicity for all of the teachers. Amani's change was static then dynamic, Tima's change was dynamic then static, Sara's change was dynamic, and Hazem's change was static then dynamic.

An example is the case of Sara, her first student-centered discovery activity was the activity she applied in her first lesson of the intervention. In this lesson she sensed the importance of discovery activities and how this students motivated the students and she said:

I gave them four cases with aim of acquaint to GeoGebra trace, animation, and sliders. They liked a lot so and got their attention and interest. Gave them the function act printed and they started working, one student volunteered to help me... Students enjoyed a lot the activity and attained all the required objectives. They could see things (Interview 2, November 7, 2015).

A second example is Hazem' case, the intervention did not affect the place where Hazem uses GeoGebra. He mentioned *availability of a computer lab and/or the accessibility to the laptops* (ZFM) to be the only barriers to more extent of using GeoGebra in his teaching. He did overcome that barrier by asking every student to bring his own device mainly tablets. Since his first interview Hazem affirmed his continuous use:

I am willing to use GeoGebra if it is related to my lesson, I consider working with GeoGebra as 'clean work' contrary to board drawing (draw, redraw...). I encourage my students to use it; I already introduced them on its features and how to use. (Interview 1, November 7, 2015)

In his second interview he said: "all students contributed [in the activity discussion], to a certain extent, according to their motivation. If they bring their own device things would be more beneficial." (Interview 2, February 11, 2016)

Summing up, due to the intervention the extent of using GeoGebra for discovery by students in the computer lab increased. For all categories of the practices the *accessibility* and *availability of hardware* were the main negatively mediating factors to higher levels of practices for all participants. The general pattern of change in the practices was more from static to dynamic in the *stages of use*, static in the *method of use* and in the *place of use*.

## Discussion

It seems that unlike the medical or the industrial fields, the educational field is more complex in integrating technology in terms of social and psychological factors of all the stakeholders.

In the medical field for example the instrument for measuring blood pressure is one tool that is used for all people, young or old, under-weight or over-weight... To use this instrument or an updated version of it does not require social acceptance or/and making the medical staff believes of its importance. On the other hand, in the educational field there is no technology that fit all ages, abilities, and intelligence levels... Deciding to use any instrument in a certain class needs to pass many filters in order to be an integral part of the teaching-learning process.

## Recommendations

To see change in mathematics teachers' extent of using GeoGebra in particular and technology in general it seems one day workshop is not the perfect choice according to this study. Maybe with such professional development teachers' knowledge might change quickly but more has to be done in order to change their practices. How should universities prepare their pre-service teachers to be ready to use technology most of the time in their teaching? How should professional development be designed to make sure teachers' practices are changed regarding integrating technology in teaching? Maybe this study answers some of these questions but more work still needs to be done to solidify them.

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