EFFECT OF GEOGEBRA COLLABORATIVE AND ITEARTIVE PROFESSIONAL DEVELOPMENT ON IN-SERVICE SECONDARY MATHEMATICS TEACHERS' TPACK

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This study aims at understanding the effect of collaborative and iterative GeoGebra intervention on in-service mathematics teachers GeoGebra adoption in their teaching and the factors that mediate that adoption. This article is one out of four parts of the study. The type of the study is a multiple case studying in depth the effect of a GeoGebra (a free mathematics software) intervention on the Technological Pedagogical Content Knowledge (TPACK) of in-service mathematics teachers in secondary schools who follow the Lebanese curriculum. The methodology used 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 level of TPACK domains of teachers especially in their student-centered teaching approach.

Keywords: In-service secondary teachers PD, GeoGebra, TPACK.

INTRODUCTION

To effectively integrate technology in their classrooms mathematics teachers need to have good mathematical content knowledge, technological knowledge, pedagogical knowledge, and more importantly a mix of all of them as TPACK. In addition, they need to know what barriers they might face when they integrate technology in their classes and how to overcome them.

Literature review

The previous research on using technology in teaching of mathematics is so rich. For example between 2012 and 2017 there were more than 15000 articles about GeoGebra, more than 5000 on mathematics teachers' TPACK. But there is around hundred combining both (Google scholar advanced search, August 2017). Very few of these hundred studies address in-service secondary mathematics teachers and their practices. After reading and analyzing all relevant literature the following was found. First, research on technology integration lately is focusing on the design, implementation, and impact of tasks that are intended for prospective and practicing teachers for their professional learning concerning technology use in classrooms. (European society for Research in Mathematics Education ERME book, in print). However, "research on the application of these theories [theories on technology integration and teachers' knowledge] within the design of tasks intended for teachers' professional learning initiatives is still in its infancy." (ibid)
Second, in a recent meta-analysis concerning all the articles written about the issue of using technology in upper secondary mathematics education reported four striking issues (Hegedus,et.al., 2017). One of them was the gap between teachers' needs and the teacher education contents which is an under-represented issue in the field of mathematics education research. Third, there is evidence of GeoGebra being used extensively around the globe; it has been translated into fifty four languages and has been used by approximately more than millions of teachers worldwide for more than 15 years now (Hohenwarter, GeoGebra Global Gathering 2017). However, systematic enquiries into the effectiveness of GeoGebra in teaching practices are limited. (Lu, 2008). One of the studies concerning GeoGebra and TPACK worked with 44 prospective secondary mathematics teachers enrolled in two methods courses. One of the results was that creating dynamic activities is essential to the development of teachers' TPACK. One of their recommendations was that we can deepen prospective teachers' knowledge of teaching and learning mathematics with technology by creating a rich and collaborative learning environment and challenging them with new problems, new pedagogies, and new solutions associated with the use of technology. Fourth, it terms of TPACK it was found that the *Technology, Pedagogy and Content Knowledge* (TPACK) framework

(Mishra & Koehler, 2006) is a dominant frame used to address teachers' professional knowledge and skills (ERME book). Recently, despite the large number of researches done on TPACK, one research recommended "further research through participant observation studies…to ascertain the nature, magnitude, and direction of the interaction among teachers' TPACK elements and the reality of school contexts" (Handal , Campbell, Cavanagh, Kelly, & Petocz, 2013, p. 36). The changes in teachers' knowledge can lead to the changes in their classroom practices and that these changes can be reliably measured by the TPACK survey (Shin, Koehler, Mishra, Schmidt, Baran, & Thompson, 2009). Finally, though there has been a flowering of research on TPACK and its measurement, the review indicates that there is still much to be done particularly in the area of measuring how TPACK works in different disciplinary contexts. The quality of research has also been patchy, and there is a clear need for better-designed studies and instruments. (Koehler, Mishra, Kereluik, Shin, & Graham, 2014)

Summing up, this research aims to study how a collaborative and iterative work with in-service mathematics teachers affects their GeoGebra integration level in their teaching. Accordingly, this study aims to answer the following research questions:

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

Theoretical framework

In this study we have selected three theories namely: The zone theory, the diffusion of innovation theory, and TPACK (Technological Pedagogical Content Knowledge).

The Zone Theory states that the factors affecting technology usage by teachers are categorized into three zones namely zone of proximal development (ZPD, includes skill, experience, and general pedagogical beliefs), zone of free movement (ZFM, includes access to hardware..., support, curriculum and assessment requirements, students...) and zone of promoted action (ZPA, includes pre-service education, practicum and professional development) (Goos et al., 2010). TPACK claim that whenever new technology is to be effectively employed, teachers need to develop dynamic equilibrium among three elements, namely, technology, pedagogy, and content (Mishra and Kohler , 2006). The diffusion of innovation model describes the stages a person goes through when making the decision to adopt or reject a new technology (or innovation). It includes the following stages: (a) knowledge, (b) persuasion, (c) decision, (d) implementation, and (e) confirmation. Niess et.al. (2009) combined TPACK and the diffusion of innovation theories to obtain a new model called the "TPACK development model". In this study we have used that model with Valsiners' zones.

Methodology

Design Based Research (DBR) methodology in three iterations was used in this study over two stages (Figure 1). The first stage is the pre-intervention stage. This 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 3 hour-workshop was conducted by the researcher with the four participants to make sure all participants acquired the basic features of the software (GeoGebra). In addition, as a group we collaborated in discussing the topics in the secondary mathematics Lebanese curriculum that could be better taught with the use of GeoGebra. We found that GeoGebra can be used in 37 different lessons of the secondary Lebanese curriculum. The second stage was the intervention stage which was made up of 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 free 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 Design Based research. The last visit was to evaluate the second lesson and give a general overview of the whole experience.
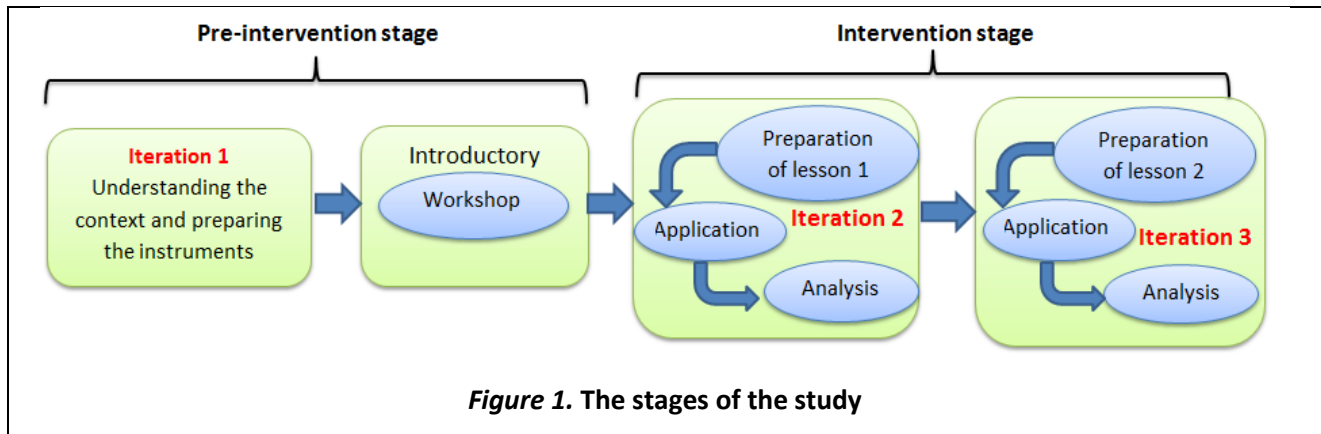

Figure 1. **The stages of the study**

Instruments

For the pre-intervention phase, three questionnaires were administered by the participating teachers: (1) Demographics questionnaire, (2) The Technological Pedagogical Content Knowledge Development Level Questionnaire TPACKDLQ (Form 1), (3) Barriers (grouped in zones) in Using Technology Questionnaire BUTQ (Form 1). The purpose of these questionnaires was to measure teachers' current TPACK integration level of the GeoGebra software in their teaching and the barriers that affect their technology integration. The questionnaires were adapted from TPACK development model (Niess, et.al, 2009). After conducting the first lesson, semi-structured interview in parallel form of the previous pre-intervention instruments TPACKDLI (Form 2) and BUTSI (Form 2) but combined were used to measure the impact of the intervention on teachers' TPACK 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 instrument is Lesson Assessment Criteria semi-structured Interview (LACI) which is based on instrument by Harris, Grandgenett & Hofer (2010).

Niess et.al (2009) combined the four categories of TPACK: (a) curriculum and assessment, (b) learning, (c) teaching, and (d) access, with the five levels of the diffusion of innovation theory: (a) recognizing (knowledge), (b) accepting (persuasion), (c) adapting (decision), (d) exploring (implementation), and (e) advancing (confirmation). The results of this combination are eleven domains that constitute the TPACK development model. Each domain is made up of a five-scale that measures teachers' level of integrating a particular technology in teaching and learning mathematics. In this study we adapted this instrument to ask specifically about GeoGebra.

For the impact of the intervention we were interested in the change of the TPACK integration level of GeoGebra at the end of each implementation, whereas for the dynamicity we were interested in the pattern in which this change happened in between the implementation stages: 'before implementation', 'after implementation 1', and 'after implementation 2'. The dynamicity could be: (1) static: there was no change in the level in between the implementation stages or (2) dynamic: there was a change in the level in between the implementation stages. In this sense after the two

lessons a general pattern could be static (across the 2 iterations), dynamic, (across the 2 iterations) static (no change) then dynamic (change) or dynamic (change) then static (no change).

Participants

In the last (sixth) workshop conducted by the researcher for the study attendees were given the pre-intervention questionnaires mentioned above and another questionnaire that measures the extent of using the GeoGebra in their practices. 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. An average within the range [0, 0.7[is considered low integration level, an average between [0.7, 1.3] is moderate integration level, and between]1.3, 2] a high integration level. 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
Haze	41-50	Masters	31 years	High	Moderate	Not	Not

Table 1. Participants domographics, practice and zones level
*Not: the zone is not considered as a barrier to GeoGbera integration

GeoGebra modules

The criteria used for lesson selection are based on the criteria 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 which activities applied by each teacher. An example of one activity is provided at the end of the article.

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

Table 2. **The intervention activities conducted by each of the participating teachers**

RESULTS

The median of all eleven domains for each participant before, after first implementation, and after second implementation were calculated and the results are shown as box plots in Figure 2.

It was found that before the intervention the median result for all cases is the *adapting* level, after the first implementation the median−for most cases−improved to the *exploring* level but many subcategory levels stayed in the *adapting*, whereas after the second implementation the median− for most cases−stayed at the *exploring* level but with less subcategory levels on *adapting* and more on the *advancing* level.
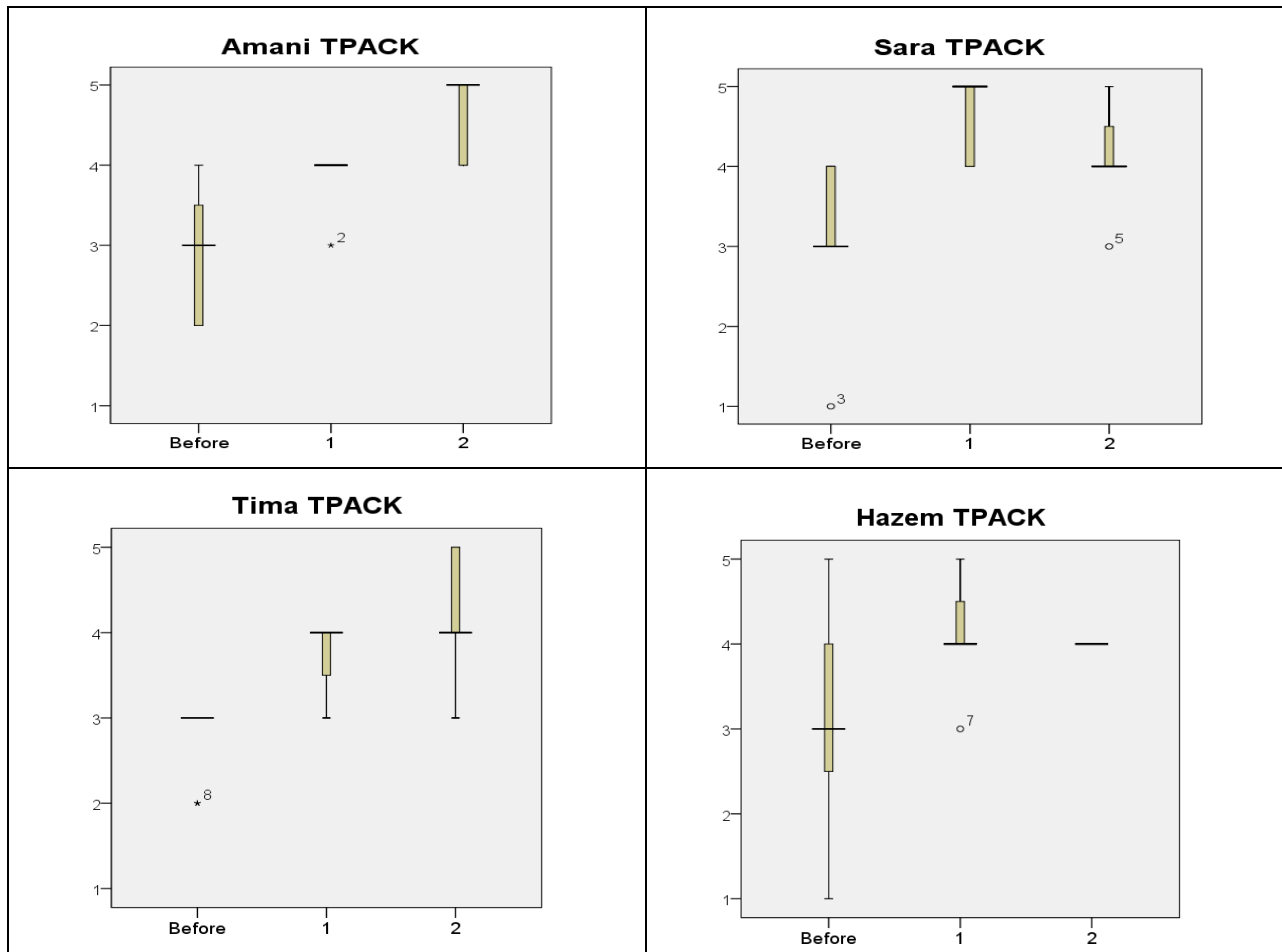

Figure 2. The effect of the intervention on participants' TPACK level

Iterations: Before: before the intervention; 1: after first implementation; 2: after second implementation

Levels: 1 *recognizing*, 2 *accepting*, 3 *adapting*, 4 *exploring*, and 5 *advancing*

Based on the details of the results and to answer the research questions we can say the intervention done iteratively and cooperatively improved all TPACK domains for all the participants: (1) teachers learned and experienced how to effectively integrate GeoGebra in their curriculum, (2) they started using some kind of GeoGebra assessment questions, (3) they started using more student-centered activities that require more critical thinking skills, and (4) they sensed they need more professional development in GeoGebra and in technology integration in general.

Most of the mediating zone factors were overcome except some related to the zone of free movement (ZFM) that came in the way of reaching higher levels. Those ZFM factors were: (1) *curriculum requirements* because not all lessons are appropriate to be taught with technology, (2) *lack of hardware (or not enough), and* (3) *students' motivation.*

For the dynamicity of change it was found that eight of the eleven domains of TPACK development model were dynamic then static, two domains were dynamic specifically the professional development and overcoming barriers, and lastly one static (to a certain extent) domain which is mathematical teaching.

For most cases before the intervention, most participants' subcategories were in *adapting* level and after two iterations they reached either the *exploring* or the *advancing* level (highest TPACK level). The change was mostly dynamic with change happening immediately after the first implementation. There were some assisting factors to higher TPACK levels mainly *collaboration* (ZPA), *increase in knowledge and skills* (ZPD), and some ZFM factors like *availability of hardware, curriculum requirements and students' motivation*. The limiting factors were mainly ZFM factors such as: *not enough available or accessible hardware, lack of time to prepare and conduct GeoGebra activities, students' motivation, and curriculum requirements…* and one ZPD factor *lack or not enough skill.*

DISCUSSION

It was clear from the dynamicity of change the direct effect of the intervention on teachers' TPACK in all its eleven domains. Not only it raised the adoption level of GeoGebra in their teaching but also kept that adoption high. In addition, as a direct impact on collaboration and applying GeoGebra activities in their teaching teacher felt the need of learning more about this software and how to effectively integrate it in their teaching. In fact, many after the intervention attended other workshops conducted by the researcher and kept on using GeoGebra in their teaching. Sometimes teachers' perception of the barriers is not related to reality and that we have seen when they changed their list of barriers before the intervention and after. One important factor acted sometimes as encourager and sometimes as barrier to higher integration level was students' motivation.

RECOMMENDATIONS

In terms of the research questions, can we say that the effect of the design as collaborative and iterative manner is more powerful than one-day-workshops? Does the effect of such intervention affect teachers' knowledge more than teachers' practices? The study is an ongoing one and much to be discussed in its four parts to get a clearer and better picture of the integration of technology problem.

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Example of a part of an activity

<u>Objective:</u> Understand the definition of derivative.

Given the function f defined by: $f(x) = x^2 + 3x - 4$. Let (P) be its representative curve in an orthonormal system.

    A) In the input bar type $f(x) = x^2 + 3x - 4$. Let A(-2,-6) and B $(x, f(x))$ be two points of (P).
    B) Join A and B by a straight line and specify its slope.
    C) Change the position of B and note what is happening to the slope of (AB).
    D) Can x be -2 in the slope of (AB)? _____.
    E) Can it be near -2? _____.
    F) As point B approaches point A, the slope of (AB) approaches_____.

    G) Prove that the slope of (AB) expressed in terms of x is: Slope of (AB) = $\dfrac{x^2 + 3x + 2}{x + 2}$.

    H) Calculate $\lim\limits_{x \to -2} \dfrac{x^2 + 3x + 2}{x + 2} =$ What can you deduce?_____.

    I) Can we call the line (AB), with respect to (P), in this case a tangent? _____.

Conclusion: The slope of the tangent to (P) at point A of (P) with abscissa

    $x = -2$ is equal to $\lim\limits_{x \to -2} \dfrac{f(x) - f(-2)}{x - (-2)}$.   It is also called the **derivative** of f at $x = -2$.