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. What made things more challenging to educators, teachers, parents as well as students is the availability of technology. 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. However, there was little impact on how teachers used GeoGebra in teaching and learning as well as inside or outside the classroom.

Keywords: Technology integration, PD, in-service secondary teachers, GeoGebra, DBR.

Introduction

When new technologies appear in medical or industrial fields, we see 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 because a lot of factors are involved in adopting technology and the rate of change in the education field is known to be slow.

Literature review

Research studied in detail 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; Tondeur, van Keer, van Braak, & Valcke, 2008). Second, there is a big gap between research and practice. The ongoing challenge of understanding technology integration problems is of three folds: (a) previous research done on the integration of technology in teaching has had unrealistic expectations for technology-based reform, (b) there is no consensus on research questions and methodologies, and (c) the role of research in making changes in educational practice is not well emphasized (Shrum, 2011). 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 (Lavieza, 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). The problem is deeper than it seems to be. The teacher is a key factor in this respect because teachers’ successful experiences with technology greatly influences both their persistence in using technology and their willingness to integrate technology in their classes (Ertmer & Ottenbreit, 2009). Therefore teachers should be able to actively participate in that process of technology integration (Voogt et al., 2011). 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). Lastly, most research used one theory which led to partial understanding of the technology integration problem. This is due to the nature of the subject under study (math education) that can be viewed from different theoretical perspectives, e.g. cognitive, semiotic, or social.

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’ practices regarding integrating GeoGebra in their teaching?
2. How do participants’ Valsiner’s three zones mediate the impact of the intervention on teachers’ practices regarding GeoGebra integration in their teaching?

Theoretical framework

In this study we have used the zone theory (Valsiner’s three zones) which states that the factors affect teachers’ use of technology are 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

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.
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 integration practices of the GeoGebra software in their teaching and the barriers (grouped in three zones) that affect their technology integration. The questionnaires were developed by the researcher, reviewed by three professors in mathematics education and piloted for internal validity. The value of Cronbach alpha was >0.9. After conducting the first lesson, semi-structured interview parallel form was used; IPGSI (Form 2), 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 instrument is Lesson Assessment Criteria semi-structured Interview (LACI) which is based on instrument by Harris, Grandgenett & Hofer (2010).

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. 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.

<table>
<thead>
<tr>
<th>Name</th>
<th>Age</th>
<th>Highest degree</th>
<th>Teaching experience</th>
<th>Practice level</th>
<th>ZFM</th>
<th>ZPA</th>
<th>ZPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amani</td>
<td>50-55</td>
<td>BS</td>
<td>25 years</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Tima</td>
<td>23-26</td>
<td>Masters +TD</td>
<td>2 years</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Not*</td>
</tr>
<tr>
<td>Sara</td>
<td>33-40</td>
<td>BS</td>
<td>7 years</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>Not</td>
</tr>
<tr>
<td>Haze</td>
<td>41-50</td>
<td>Masters</td>
<td>31 years</td>
<td>High</td>
<td>Moderate</td>
<td>Not</td>
<td>Not</td>
</tr>
</tbody>
</table>

*Not: the zone is not considered as a barrier to GeoGebra 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 type and place of activities applied by each teacher. An example of one activity is provided at the end of the article.

<table>
<thead>
<tr>
<th>Activity 1</th>
<th>Place</th>
<th>Activity 2</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amani Sign of quadratic polynomials</td>
<td>In class</td>
<td>Derivative</td>
<td>In lab</td>
</tr>
<tr>
<td>Tima vectors</td>
<td>In lab</td>
<td>3D</td>
<td>In class</td>
</tr>
<tr>
<td>Hazem Equation of a straight line</td>
<td>In class</td>
<td>Thales Theorem</td>
<td>In class</td>
</tr>
<tr>
<td>Sara Translation of functions</td>
<td>In lab</td>
<td>Vectors</td>
<td>In lab</td>
</tr>
</tbody>
</table>

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

**Results**

**Extent of use of GeoGebra**

The pattern of impact was the same for the extent of use of GeoGebra for lesson presentation, lesson implementation, and lesson enhancement but different for assessment. Figure 2 shows that 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.

![Figure 2. The extent of using GeoGebra by the participating teachers over the three stages: Before the intervention, after implementing the first lesson, after implementing the second lesson.](image)

For the extent of use of GeoGebra the intervention resulted in:

1) an increase in most parts of the extent of use of GeoGebra mediated positively by teachers’ ZPD.
There was interdependence between confidence and the extent of use. Teachers’ use of GeoGebra activities led to an increase in teachers’ confidence which in turn led to an increase in the extent in using GeoGebra in their teaching. For example, Tima gained more confidence and skills (ZPD) necessary to implement GeoGebra in her teaching. In our third meeting she said:

After this experience (the three iterations working with GeoGebra) not only I became more confident in using GeoGebra but also I became more confident to teach my students. Sometimes students ask strange and difficult questions use but now I am more confident since I can imagine the figures (3 D figures) better than before. (Interview 3, February 22, 2016)

2) low impact on using GeoGebra in assessment mediated negatively by teachers’ ZFM.

Three particular ZFM factors negatively mediated the impact of the intervention on assessment. These factors are: (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 in which teacher have no say on changing them. For example, Amani said in her second interview: “Till now we have not and probably be will not change the assessment but may be later we can since now there is lack of availability and accessibility of all students to computers and the assessment policies.” While in her third meeting she said:

I gave them extra grades on the activity they worked on and I have changed some assessment items because students are visualizing things now; and this is something I never attempted before. (Interview 3, December 5, 2015)

3) an increase in teachers’ appreciation of GeoGebra as a teaching tool due to the characteristics of the activities.

The characteristics 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) the strong fit of the activity with the instructional strategies each teacher uses.

For example, Hazem said after implementing the activity:

The activity was straight to the point and it optimally supported the curriculum requirements. This activity was tailor-made and easily done by students... I used to do things differently. (Interview 2, February 11, 2016)

Application

The application part asks participating teachers how they use GeoGebra in their teaching, i.e. how often they use it for 1) lesson presentation, 2) students’ presentation, 3) conducting discovery activity done with the help of students, 4) conducting discovery activity done by the students, 5) modeling or visualizing a problem. In this part the intervention had either a slight or no effect on most parts of the application category. On the other hand it had an important effect on increasing the use of conducting discovery activities done by students in the computer lab, i.e. teaching with technology became more student-centered. This part of the practices was minimally mediated by teachers’ ZFM. Teachers mentioned the accessibility to the computer lab and curriculum requirements as barriers to higher level of applying GeoGebra in their teaching.

For example the breakthrough for Tima was the use of GeoGebra in ‘conducting discovery activities done by the students in the computer lab. Tima never used such discovery activities before also that was her first use of the computer lab in her teaching. Both activities were supposed to be conducted in the computer lab, but the outdated computers and the low possibility of reserving the computer...
lab did not allow the application of the second lesson to be done in the computer lab (all ZFM factors). A second example is what Sara 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 the secondary school students. Frankly, I will not use GeoGebra with an LCD in the class to show students such things, there is nothing called ‘to show’ it is not effective only to show them…when they do it, it is different even for me I felt different. (Interview 2, November 7, 2015).

A third example is what Hazem 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)

**Place of Use**

Similar to application category, there was either no or slight effect of the intervention on the extent of use of GeoGebra in their classroom, computer lab, or at home. The intervention affected to a certain extent the use of GeoGebra at home by the participants whereas it had a minor effect of its use in the computer lab. Three out of the four teachers tried one or both of the GeoGebra lessons for the first time in the computer lab. Teachers ZFM and ZPD mediated negatively the effect of the intervention on teacher’s place of use. The factors were: (1) the availability of/accessibility to the computer lab (ZFM), (2) students’ motivation (ZFM), and (3) the teaching method (ZPD) each participant adopted in applying the activities.

In summary, GeoGebra intervention done cooperatively and iteratively increased in-service secondary mathematics teachers GeoGebra usage in their practices regarding lesson presentation, lesson implementation, and lesson enhancement. But it had a minor effect on assessment. The participants’ background in general slowed the process of integrating GeoGebra in their teaching. Teachers’ ZFM (e.g. the lack of updated hardware) mediated negatively the impact of the intervention on their practices. In addition, the intervention had an important effect on both the increase of use in conducting discovery activities done by students in the computer lab and on participants teaching method with technology to become more student-centered. Also in this part teachers’ ZFM played a negative role. The accessibility to the computer lab and students’ motivation were acting as barriers to higher levels of GeoGebra application. Lastly, the intervention affected to a certain extent the use of GeoGebra at home by the participants whereas it had a minor effect of its use in the computer lab. Teachers ZFM and ZPD mediated negatively the effect of the intervention on teacher’s place of use. For instance, when students showed motivation to conduct the activity in the computer lab the teacher was encouraged to repeat that and the opposite applies. Other factors were the availability of/accessibility to the computer lab (ZFM), and the teaching method (ZPD) each participant adopted in applying the activities.

**Discussion**

Despite the fact that the four participating teachers started with different practice levels and different zones levels they all, to a certain extent, after the intervention reached higher integration level of GeoGebra in their teaching and could overcome most of the barriers they faced. These teachers attended at least one workshop on GeoGebra conducted by the researcher. Some of the activities used in the intervention were introduced in the workshop but teachers’ practices did not change due to many reasons some of them were real and others were imaginary. But with collaboration and iterations these same teachers used those same activities in their practices and they could overcome most of the barriers related to any zone. Because with collaboration and iteration teachers feel more confident to try applying the activities and once that successfully
happens most barriers start to disappear or to be overcome. For example, Hazem could overcome lack of accessibility to hardware by asking his students to bring their own devices. Tima could overcome the same problem by using her own laptop and an LCD.

**Recommendations**

According to what I have experienced in this study I am confident that one-day workshop may affect teachers’ knowledge but it rarely changes teachers’ practices. Changing practices needs something more than knowledge. Based on this study, if the aim is to integrate technology in teachers’ practices the following steps should be followed: first, teachers should apply some ready-made activities that are strongly related to their curriculum. Second, teachers should collaborate with professional peers or researchers in order to prepare, apply and reflect on those activities. Third, teachers should try to prepare (or at least adapt) other activities by themselves with minimum support from professionals.

**References**


Law, N. (2008). Teacher learning beyond knowledge for pedagogical innovations with ICT.


**Example of a part of an activity**

**Objective:** 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) = \( \frac{x^2 + 3x + 2}{x + 2} \).

H) Calculate \( \lim_{x \to -2} \frac{x^2 + 3x + 2}{x + 2} = \) _____________.

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 \( \lim_{x \to -2} \frac{f(x) - f(-2)}{x - (-2)} \). It is also called the **derivative** of \( f \) at \( x = -2 \).