Invited Lecture

Introducing the Ladder and Slide Framework: A New Visual Framework of Mathematics Teacher Levels of Integrating Geogebra in Their Teaching

Kasti Houssam[1]

ABSTARCT The diffusion of technology in the teaching and learning is more complex than other fields. In order to understand the complexity of the factors and processes affecting teachers' integration of technology, in mathematics education in particular, we need to use many complementary lenses. For that end, in this study, we have used three theories: the technological pedagogical content knowledge (TPACK), innovation diffusion theory (IDT), and the zone theory. TPACK describes the types of *knowledge* that teachers need to integrate technology effectively in their teaching practices. IDT describes the developmental *processes* that individuals go through as they adopt/reject a technological innovation. While the zone theory identifies the limiting and assisting *factors* teachers face when they decide to integrate technology in their teaching. The result of this study was a new framework named the *Ladder and Slider* framework to introduce the three theories together using the networking theory. The purpose of the Ladder and Slide framework is to visualize easily the complexity of technology integration, consequently that will influence a better design of professional development. A pilot phase done with four in-service secondary mathematics teachers using GeoGebra in their teaching is presented with the new framework followed by some conclusions and recommendations.

Keywords: GeoGebra; DBR, Zone theory; PD; TPACK; Ladder and Slide.

1. Introduction

The integration of technology by teachers in their lessons depends on many factors. A teacher must have the required knowledge, the availability of some assisting factors and the ability to overcome limiting or hindering factors. In addition, there are many levels for that integration such as recognizing the importance of the technology, accepting it, adapting the lessons using technology, exploring further the role of technology in lessons, and accelerating in the use of technology in teaching. The required knowledge is best reflected by the Technological Pedagogical Content Knowledge (TPACK) (Koehler and Mishra, 2008). The factors, limiting or assisting, are categorized by the zone theory suggested by Goos (2005), and the different levels

[1] Foundation department, Mathematics Department, Qatar University, Doha, Qatar. E-mail: helkasti@qu.edu.qa

of technology integration are explained by the Innovation Diffusion Theory (IDT) (Rogers, 1995). As a result, no one theory or framework can capture the complexity of integrating technology in lessons. Coordinating and combining many theories will result in better analysis of the issue. For that end, Niess et al. (2009) combined the two theories TPACK and IDT and constructed the TPACK development model.

This study suggests an updated framework under the name of the Ladder and the Slide (LS). This was a result of a PhD thesis that was done over seven years using design-based research over many iterations (Kasti, 2018). The new framework used the coordinating and combining method of networking theories by Prediger, Bikner-Ahsbahs, and Arzarello (2008) to add to the TPACK development method the zone theory as an attempt to fill in the gaps of the "how" and "why" teachers' technology integration level changes.

In what follows a summary about each of the theories.

2. Literature Review

2.1. TPACK

Building on Shulman's (1986) work of PCK, Mishra and Koehler (2006) developed technological pedagogical content knowledge (TPACK) which is the knowledge of how to integrate appropriately certain technological tools to constructively teach a particular domain. As indicated in Fig. 1, to be an effective teacher he/she does not only need to know the content of his subject matter, some pedagogical knowledge, and some technological knowledge but rather the teacher should know how to use the triple knowledge as way to facilitate learning for students to make it more effective, efficient and engaging.

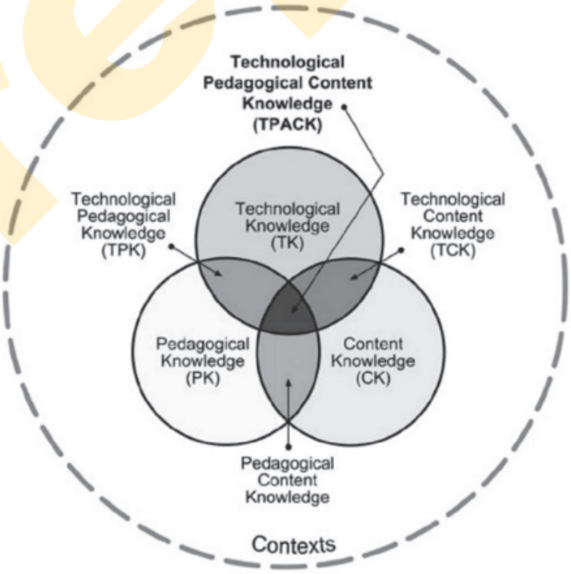

Fig. 1. The TPACK framework (Koehler et al., 2014)

One of the false expectations of change in teachers' professional practice is only increasing their pedagogical knowledge (e.g. Ottenbreit-Leftwich and Ertmer 2010; Heitink et al. 2017). One of the reasons could be that, the focus is more on the positive impact of TPACK professional development courses on teacher' perceived TPACK confidence (Chai and Koh, 2017; Doering et al., 2014) and less on the issue of pedagogical change. As Niess (2009) mentioned one of the main gaps in TPACK is being focusing more on knowledge and less on the process, in more details:

> Although the Mathematics Teacher TPACK Standards and Indicators set goals for technology integration, the standards themselves do not provide information on how teachers progressively gain this integrated knowledge for appropriately teaching mathematics with suitable technologies. This recognition raises important questions. How does TPACK develop? Is there a process in which teachers gain mathematics TPACK knowledge? Do teachers suddenly display this knowledge in their professional practice? What is needed is a model that captures the progression of mathematics TPACK as teachers integrate technology into the teaching and learning of mathematics. (Niess, 2009, p. 9)

This gap led Niess et al. (2009) to propose a developmental model for TPACK emanating from Rogers' (1995) model of the innovation-decision process (first introduced in 1962 concerning societal diffusion of innovations). Rogers described a five-stage, sequential process by which a person makes a decision to adopt or reject a new innovation.

In what follows, we will introduce the diffusion of innovation theory then present Niess et al. TPACK development model.

2.2. Innovation Diffusion Theory (IDT)

Roger's (1995; 2003; 2011) Innovation Diffusion Theory (IDT) is the most prominent and widely-used theory to explain the stages an individual, or group of individuals, decides to adopt an innovation (Sträub, 2009). It has been used across disciplines in more than 6000 research studies and field tests to comprehend and predict change, making it the most reliable in the social sciences (Robinson, 2009). An innovation as defined by Rogers (1995) is "an idea, practice or object that is perceived as new by an individual or other unit of adoption" (p. 11). The innovation does not necessarily mean better or objectively new. The decision to adopt an innovation occurs in five phases (Fig. 2 on the next page).

First is the *knowledge* phase when an individual becomes aware of the innovation through personal experience, mass media or social interactions. This *knowledge* phase can be initiated either through being exposed to the innovation or through necessity. The second stage is *persuasion* whereby an individual has acquired enough knowledge about the innovation to make a judgment about their preference towards it. Third, the individual makes a *decision* to accept or reject the innovation. Fourth, the

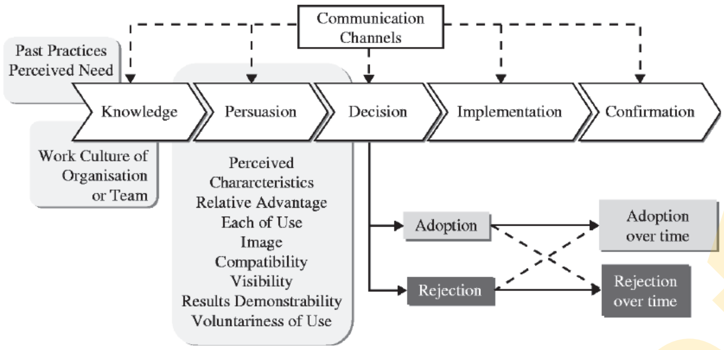

Fig. 2. The IDT framework (Rogers, 2003)

implementation stage is when the individual actually utilizes the innovation. The fifth and last stage is *confirmation* during which the individual reflects on the implementation of the innovation and determines whether they want to continue implementing it or not. (Rogers, 1995, 2003).

IDT posits that there are four primary components that impact the five stages of adoption just described, including: 1) the innovation, 2) communication channels, 3) the social system, and 4) time. These elements interact with the five stages in a process of diffusion. Niess et al. (2009) networked the TPACK and IDT in one model and called it "TPACK development model" briefed in what follows.

2.3. TPACK development model

Niess et al. (2009) combined the four categories of TPACK (Mishra and Koehler, 2006) with the five levels of IDT (Rogers, 2003). They observed many teachers, over a 4-year period, learning about spreadsheets and how to integrate spreadsheets as learning tools in their mathematics classrooms. Analysis of these observations found that teachers progressed through five-stage developmental process when learning to integrate a particular technology in teaching and learning mathematics. They called their new framework the TPACK development model (TDM). The five scale-levels of TDM are (Fig. 3):

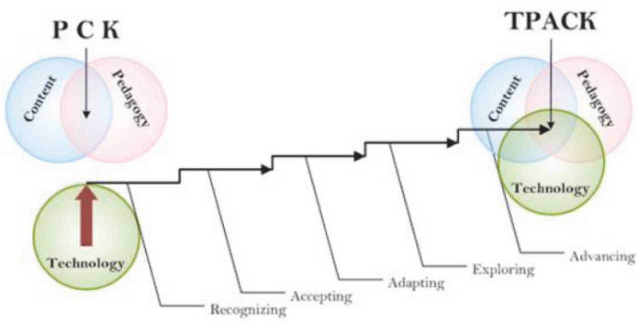

Fig. 3. Visual description of teacher levels in TPACK development model

1. *Recognizing* (knowledge), in which teachers are able to use the technology and recognize the alignment of the technology with mathematics content, yet, do not integrate the technology in the teaching and learning of mathematics.
2. *Accepting* (persuasion), in which teachers form a favorable or unfavorable attitude toward the teaching and learning of mathematics with an appropriate technology.
3. *Adapting* (decision), in which teachers engage in activities that lead to a choice to adopt or reject the teaching and learning of mathematics with an appropriate technology.
4. *Exploring* (implementation), in which teachers actively integrate the teaching and learning of mathematics with an appropriate technology.
5. *Advancing* (confirmation), in which teachers evaluate the results of the decision to integrate the teaching and learning of mathematics with an appropriate technology. (Niess et al., 2009, p. 5)

Niess et al. (2009) described the stages mathematics teachers go through since they decide to adopt certain technology until when they become professionals in using that technology in their teaching. Still the natural question that arises is what happens from one stage to another? What are the assisting and/or hindering factors that come in the way of the teacher when climbing the ladder of technology integration? To answer those questions, we need a third theory namely the zone theory briefed below.

2.4. Zone theory

Goos and Bennison (2008) mentioned that Zone Theory is based on a sociocultural perspective in which learning is viewed as a result of the complex and dynamic interaction among individuals and their environments. Zone theory was initially developed by Valsiner (1997) within the context of child development. This theory is an extension of Vygotsky's (1978) Zone of Proximal Development (ZPD) which is defined as the gap between children's independent ability and the potential performance they can reach with adult guidance or peer collaboration (Vygotsky, 1978). In addition to ZPD, Valsiner's (1997) theory includes two other components, namely: The Zone of Free Movement (ZFM) and the Zone of Promoted Action (ZPA). ZFM refers to environmental restrictions that limit freedom of thought, expression or behaviour; while ZPA refers to the efforts of more experienced individuals in promoting learning (Vasliner, 1997). Within the school context, the interactions between teachers, students, technology, and the teaching-learning environment can be clearly categorised by the zone theory. The ZPD is characterized as the gap between teachers' current technology ability and their ability that can potentially be reached with the help of more experienced individuals. It includes teachers' disciplinary and pedagogical content knowledge and beliefs. ZFM refers to external constraints that limit teachers' use and integration of technology such as student characteristics, curricular and assessment requirements, availability of technological resources and materials. ZFM also includes teachers' own interpretations of the environment which can serve as personal constraints or affordances. Finally, ZPA refers to opportunities that teachers were exposed to through pre-service teacher education or in-service professional development relating to the integration of technology. ZPA can be thought of as professional development strategies. (Goos, 2005; Goos et al., 2007) (Fig. 4). In order for teachers to successfully integrate technology in their classrooms, their ZPA should be within their ZFM and consistent with their ZPD (Goos, 2009). In other words, "…professional development strategies must engage with teachers' knowledge and beliefs and promote teaching approaches that the individual believes to be feasible within their professional context" (Goos et al., 2010, p. 26).

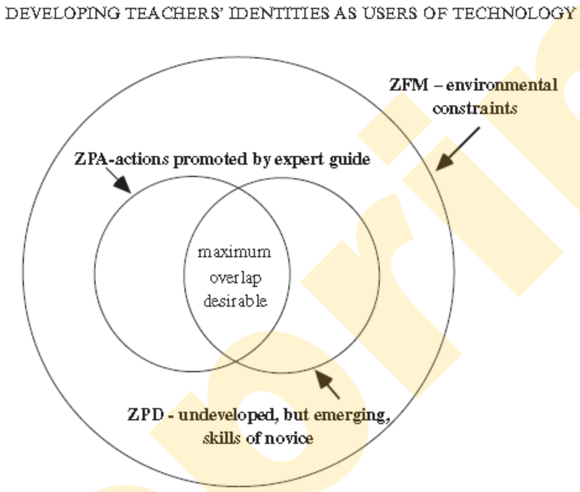

Fig. 4. Relationship between ZPD, ZFM, and ZPA for teachers

In what follows, after we have introduced briefly the three theories and the TPACK development model, we will introduce our new framework that combines the three perspectives (theories) into one visual framework. Then to bring it to life the results of a pilot study with four in-service secondary mathematics teachers will be presented (Kasti, 2018).

3. The Ladder and Slide Framework

Linking TPACK to IDT by Niess et al. (2009) adds to the necessary knowledge teachers must have in order to integrate technology in their classes the integration scale-level. This model still misses how teachers climb the ladder of technology adoption and what are the mediating factors (limiting or assisting) teachers face when they integrate technology in their teaching (Fig. 5). The zone theory suggested by Goos (2005) captures all the factors that mediate technology integration by teachers. Therefore, using the networking theories approach by Prediger, et al. (2008), the well-fitting elements from the aforementioned theories were coordinated and combined. The result is the new framework, namely, the Ladder and Slide (LS) framework.

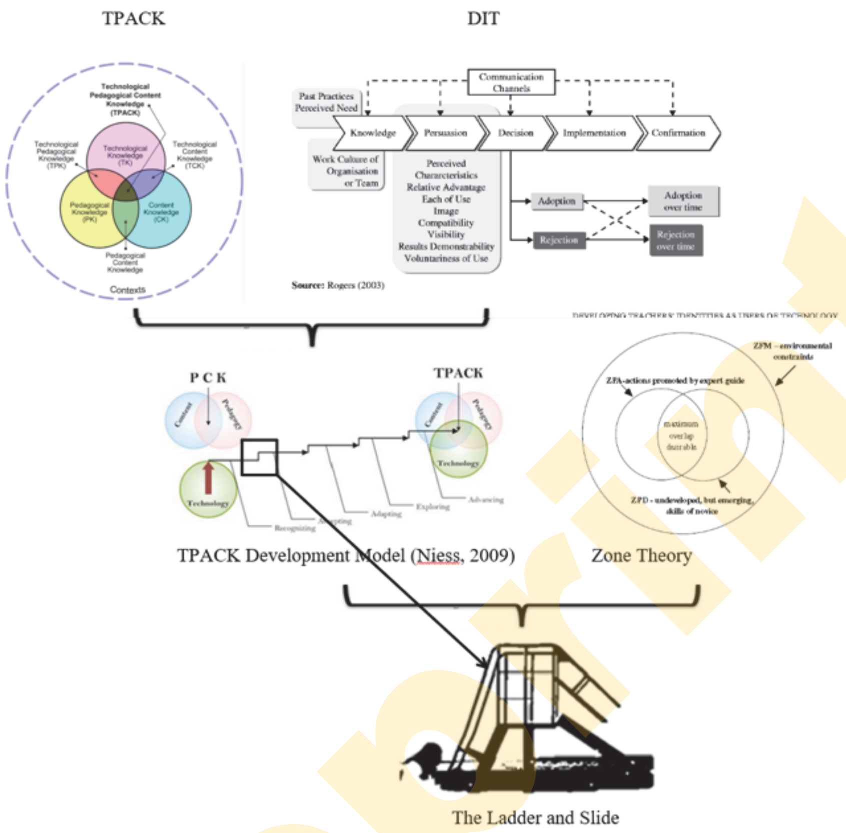

Fig. 5. TPACK development model and the zone theory combined in the new Ladder and Slide framework

Each stage represents one of the five levels described by the TPACK development model (Niess et al., 2009) To go from one integration level to another teachers face a “ladder” that has the following characteristics:

The ladder, as shown in Fig. 6, is made of three main components:

1. the main core represents the ZFM factors teachers face as limiting or assisting factors;
2. the steps represent teachers’ backgrounds and beliefs that also can assist them or limit their technology integration. In addition, these stairs represent the ZPD and ZPA of teachers, and
3. the handrail represents collaboration and iteration teachers might get in their transfer from one phase to another.

All the zones play dual roles: limiting and assisting. Hence, that was represented by the ladder in the following way. The core of the ladder represents the assisting role of the ZFM factors whereas the limiting role is represented by the degree of inclination of the ladder; the higher the inclination (slope), the stronger the impact of the limitation.

Slope less than one is weak barrier; slope equals to one is moderate barrier and slope more than one is high barrier.

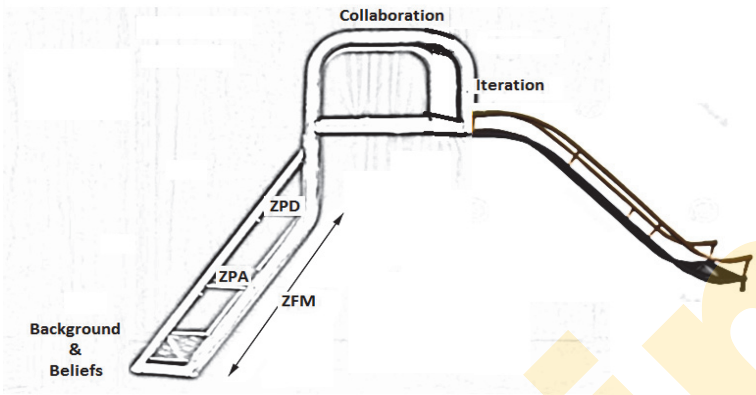

Fig. 6. The Ladder and Slide framework

Whereas, the steps represent the assisting role of the background, ZPD and ZPA. They assist teachers in moving up the integration levels. On the other hand, the limiting roles of ZPD and ZPA are represented by the position of the steps; the higher the step, the stronger the impact of the limitation factors. That is, step one is weak barrier, step two is a moderate barrier, and step three is a high barrier.

The handrails represent collaborations and iterations teachers get when moving up the technology integration levels and prevent them from sliding down again. After each level, teachers might slide down (using the slider) to a lesser integration level and that could be due to one or more factors. As the stage increases, the teachers TPACK levels and the extent of using technology in their teaching, increases. In what follows, the results of the pilot phase are represented using the framework.

4. Methodology

The methodology used in the pilot phase study was design-based research with three iterations. Many instruments were used to collect data. The main instrument was an adapted version of Niess et al. (2009). Fig. 7 displays the order of stages that were followed in conducting this research. The study consisted of a pre-intervention stage and an intervention stage.

The collaboration was between the researcher and the four participants as a group during the introductory workshop, afterwards the collaboration was done between the researcher and each of the participants at his/her own school, according to each participating teacher's free time. Each teacher was free to choose the lesson in which GeoGebra will be integrated in. There were two visits for each iteration, one before and another after the intervention (implementing the GeoGebra lesson). Before and after each lesson teachers were interviewed to measure the effect of the intervention on their practices, TPACK and barriers faced. The activity of the first lesson was totally prepared by the researcher but for the second lesson the teachers adapted a ready-made activity or prepared their activity. In what follows, design-based research methodology will be presented.

Stages

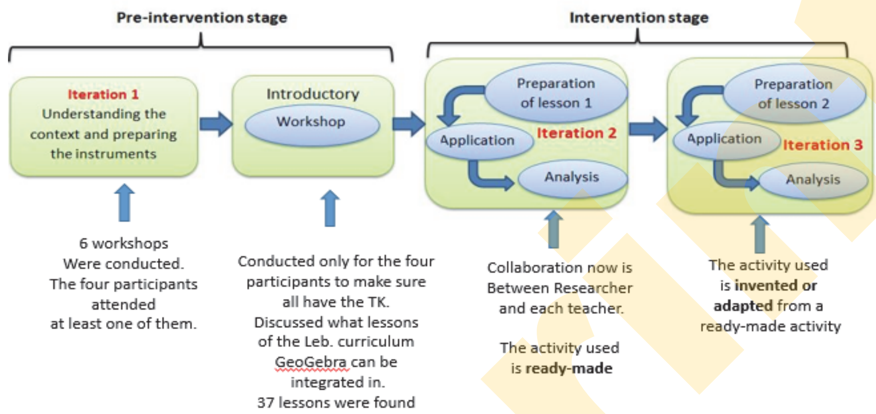

Fig. 7. The research stages as pre-intervention and intervention over three iterations

4.1. Design based research methodology

Wang and Hannafin (2005) define DBR as:

> …a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories. (p. 6)

The six basic characteristics of DBR are that it is: 1) pragmatic; 2) grounded; 3) iterative, and flexible; 4) interactive; 5) integrative; and 6) contextual (Wang and Hannafin, 2005).

DBR differs from traditional experimental designs in that it does not occur in controlled settings, but rather in naturalistic settings where myriad systemic variables are taken into account (Collins, 1992). The focus on the evolution of design principles differentiates DBR from action research and formative evaluation designs in that "the design is conceived not just to meet local needs, but *to advance a theoretical agenda*, to uncover, explore, and confirm theoretical relationships" (Barab and Squire, 2004, p. 5). Based on that the design-based research methodology was found perfectly fit for the study. The selection of participants in this pilot phase will be explained next.

4.2. Participants

The pilot study was with four participants, three females and one male. All four teachers were in-service secondary mathematics teachers. The participants were among many secondary teachers who have attended some previous workshops on the use of GeoGebra in teaching and accepted the invitation to participate in the study. But the four were particularly chosen so they differ in one or more of the zones levels. The demographics of the four participants and their starting data are summarized in Tab. 1. Teachers were interviewed and their use of GeoGebra software in their teaching was recorded; in addition, factors that limited their technology integration was recorded and grouped in terms of zones.

Tab. 1. Participant demographics, practice and zones starting level

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	N/A*
Sara	33–40	BS	7 years	Moderate	Moderate	Low	N/A
Hazem	41–50	Masters	31 years	High	Moderate	N/A	N/A

**Note.* N/A = The zone was not considered a barrier to *GeoGebra* integration.

All names are psudonames; practice level means how often did the participants use GeoGebra in their teaching; the zones were taken in the limiting sense. That is, a “Moderate ZFM” means that the teacher faced some limiting factors related to the zone of free movement. Those levels were set by the study instruments that will be listed and explain next.

4.3. Instruments

This study was an intervention study that followed a DBR methodology. It was implemented in two phases: pre-intervention and intervention, with each phase having its own set of instruments. All of the instruments were adapted by the researcher from previously tested instruments and based on multiple well-known theories. In addition, they were all administered on an individual basis with each participant in his/her school and were tape-recorded after the participant’s approval. For further details it is advised to check the complete work (Kasti, 2018).

5. Results

The results of the pilot study using the Ladder and Slide framework is reported in what follows on individual bases.

5.1. Amani and the LS Framework

Amani started the intervention considering herself as having the necessary skills (assisting ZPD) to integrate technology in her classroom, but not enough knowledge and confidence to do so (limiting ZPD). She did not receive any related preparation to integrate technology in her teaching as part of her university degree, school preparation or professional development (limiting ZPA) and had a high limiting ZFM. After implementing her first lesson, (Fig. 8), she changed her teaching methodology to be more student-centred than teacher-directed. Amani got encouraged by her students' motivation and her colleagues and administration (assisting ZFM) after conducting the activities. She still had some ZPD problems related to knowledge of the software which she overcame after her second implementation.

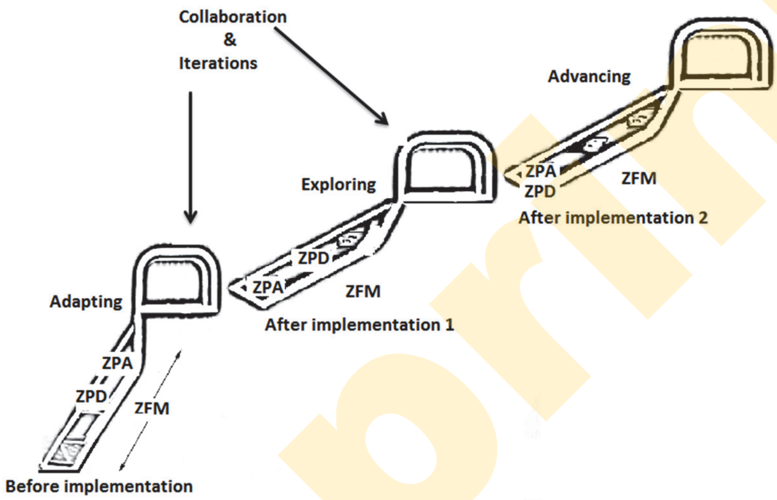

Fig. 8. Amani's story according to the LS framework

Furthermore, after her second implementation, Amani progressed to the highest level (*advancing* level), overcoming most of her ZFM limiting factors and assisted by her ZPA and ZPD factors in collaboration with the researcher. The major impact of the intervention on Amani is the increase of self-confidence. In addition, the follow-up drove her to be more committed and apply what she has learned.

When asked why she did not apply what she had learnt from the workshops she attended, she replied:

> I didn't apply due to many reasons (personal and availability of hardware) but now I am happy exploring things and learning a lot. Your presence made me work because I felt more confident, secure, and somehow ethically obliged. (Interview 1, October 17, 2015)

Amani learned a lot from the workshops she attended with the researcher, but that did not make her feel ready enough for *GeoGebra* integration. While immediately after collaborating with the researcher in preparing, implementing and assessing her first lesson, her assistive ZPA increased and continued to increase after the second lesson.

In asking about Amani's evaluation of the whole experience, she said:

> I am very happy, really happy, I enjoyed and enjoying a lot the new way [use of GeoGebra to introduce lessons], even that it is taking time and effort I am seeing videos and trying to learn more. I am enjoying (it) a lot; (I'm) really happy. (Interview 3, December 5, 2015)

5.2. Tima and the LS framework

Tima was a newly graduated teacher with only two years of experience in teaching mathematics for the intermediate and secondary classes. She found herself ready in terms of skills, knowledge and confidence to integrate technology in her classroom (assisting ZPD) despite the fact that she did not receive enough preparation on technology integration in teaching as part of her university degree, school development, or professional development (limiting ZPA; Fig. 9).

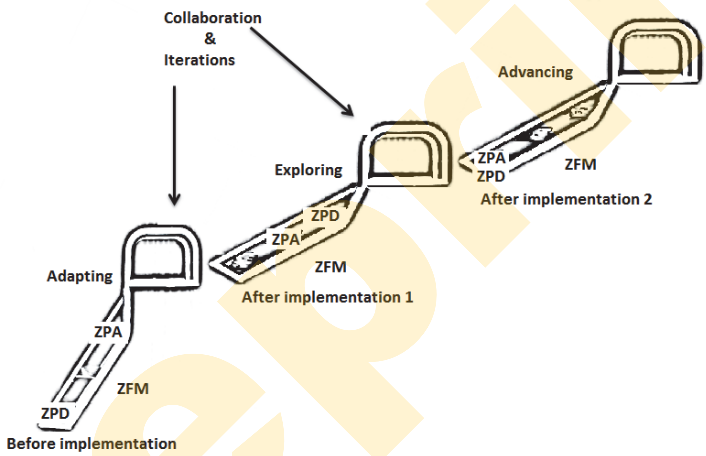

Fig. 9. Tima's story according to the LS framework

The intervention lessons were implemented in her school computer lab, but with old hardware and software and without receiving any encouragement from the administration (limiting ZFM). In the process of the intervention, Tima learned a lot and she overcame most of the barriers she faced. What hindered Tima's integration of *GeoGebra* in her teaching was her lack of knowledge of the proper methods to do that and the knowledge of the lessons to which she could apply it. Regularly, a workshop will solve this knowledge problem, but a new teacher like Tima needs scaffolding to gain more confidence. Hence, iterations and collaborations solved this big gap and allowed Tima to reach the *exploring*-*advancing* level in which she adapted *GeoGebra* for continuous use in her teaching.

After the intervention, Tima continued to use *GeoGebra* in her teaching. She stated:

> I sensed really it is powerful and now I am really a strong believer of the importance of using GeoGebra in my teaching (and I will) in all the grades I teach (intermediate and secondary). I want to teach every lesson that can

> be taught using GeoGebra. I am intending to do it. I was honored to be part of your team and learn from you. Now anything I am teaching exercises and problems I am using GeoGebra, everything is clear and easy. I even taught a colleague of mine how to draw using GeoGebra. (Interview 3, February 22, 2016)

5.3. Sara and the LS framework

Sara (Fig. 10) had seven years of experience in teaching mathematics for the intermediate and secondary classes. She found herself ready in terms of skills, knowledge and confidence to integrate technology in her classroom (assisting ZPD) despite the fact that she did not receive enough preparation on technology integration in teaching as part of her university degree (limiting ZPA). In her school, she had no computer lab, no hardware to be used in class, and no applicable software. She got no encouragement from her colleagues or administration and no technical support. The first implementation in this study was her first time she tried a discovery activity done by students in the computer lab. Students' motivation played an assistive role (assisting ZFM) and encouraged Sara a lot. She still had some ZPD problems related to knowledge about the software that she overcame after her second implementation. In the second implementation, students were not as motivated, so her expectations decreased (limiting ZFM). Her ZPA and ZPD were overcome as limiting factors and her ZFM became less steep as a limiting factor (Fig. 10) and she progressed to the highest level (*advancing* level).

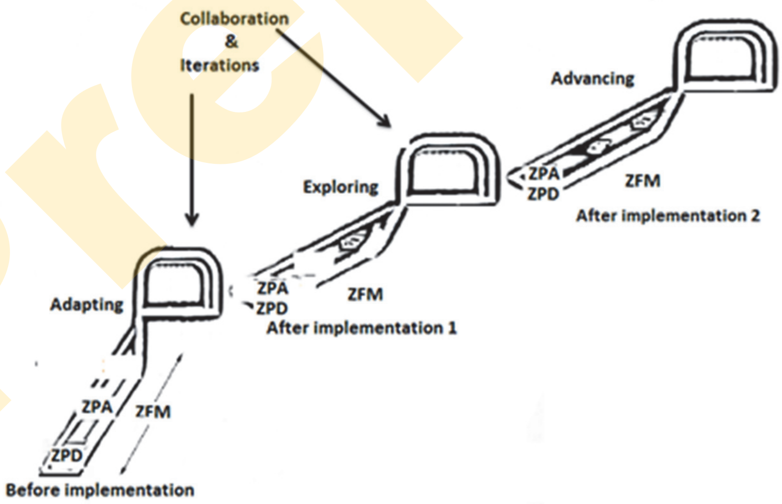

Fig. 10. Sara's story according to the LS framework

Sara could sense the difference between presenting her lesson using *GeoGebra* and letting her students explore the lesson working with *GeoGebra*, she said:

> There is a difference between when things are done by students is totally different from seeing things. The instructions were very well organized. I was impressed I felt the importance but without the availability things would be impossible or more difficult, to discover and to experience to get IT skills and math thinking skills is impossible without working in the lab. (Interview 2, November 7, 2015)

5.4. Hazem and the LS framework

Hazem (Fig. 11) has 31 years of experience in teaching mathematics for the intermediate and secondary classes. He found himself ready in terms of skills, knowledge and confidence to integrate technology in his classroom (assisting ZPD) since he has a degree in computer science (assisting ZPA). He sees students' motivation, curriculum requirements and assessment policies as the most common barriers to technology integration in his class (limiting ZFM). He overcame the availability by asking students to bring their pads or tablets with them at all times. It is evident from Fig. 11 that Hazem smoothly started his *adapting* level with just some ZFM barriers, but after his first implementation, his ZPD appeared as a limiting factor. He identified his need to know more about GeoGebra. Where as the ZFM barriers were being surpassed. After his second implementation, he reported that he was not at the *advancing* level for many reasons some of which were the ZFM barriers he mentioned before.

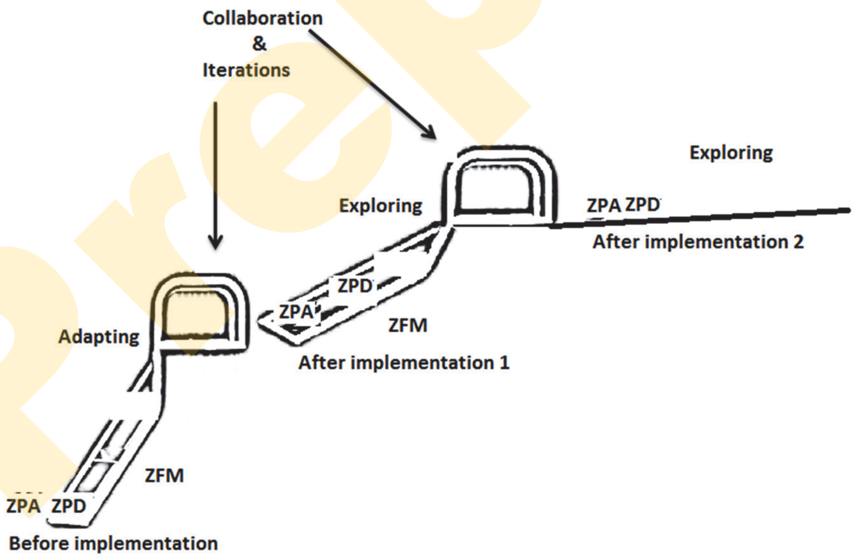

Fig.11. Hazem's story according to the LS framework

Hazem tried to overcome *availability and accessibility to hardware* by asking students to bring their own tablets or laptops. He said:

> Class is more interesting with technology but accessibility to computers was a factor (barrier) because GeoGebra is easier to use on computers than on tablets…What helped me was some students were motivated and they shared it, in general it was fine (the activity). (Interview 2, February 11, 2016)

6. Discussion

From the results shown by the Ladder and Slide framework reported for the four in-service secondary mathematics teachers we can deduce the following:

First, the fact that all the teachers in this study reported less ZFM barriers after the intervention (by seeing the slope of the slide getting less in all the four cases) means that the intervention played a role in decreasing the limiting effect of ZFM and that they were able to overcome some barriers. It may also be indicative of the fact that teachers may have anticipated encountering certain inhibiting factors (before the intervention); however, when they had hands-on experience with technology integration, they may have found that those were not the real barriers, but rather some other unanticipated ones. In fact, all of these have been mentioned as common barriers to technology integration in numerous previous research (e.g., Bingimlas, 2009; Chen, 2008; Forgasz, 2006; Lim and Khine, 2006; Oncu et al., 2008). After the intervention, the number of ZFM barriers mentioned decreased to only three which were accessibility and availability of hardware and student motivation. Accessibility and availability of hardware has been consistently reported by in-service teachers as a significant barrier to technology integration (Earle, 2002; Forgasz, 2006; Hew and Brush, 2007; Oncu et al., 2008).

Second, with regard to teachers' ZPD, the teachers were least likely to report that a gap in their knowledge, skills or confidence was an inhibiting factor. This we can see that all four participants one had their first step in the ladder a ZPD (Only one in the second step) and then we can see with iterations the step have changed. This is in contrast with previous research which reveals that teachers' lack of confidence and skills in using technology and their lack of technology knowledge are important factors in whether or not they choose to integrate technology (Boris et al., 2013; Forgasz, 2006; Lim and Khine, 2006). However, after the first implementation, the teachers of this study realized that they needed additional knowledge and skills in *GeoGebra*. This was remedied after the second implementation whereby teachers were somewhat able to fill those knowledge and skill gaps as well as boost their confidence through collaborations with the researcher.

Finally, in terms of ZPA only one participant started with low step in his ladder whereas the others started either high or medium height. That is due to a lack of adequate or sufficient training in technology integration from the findings of this study which indicated that three of the teachers reported not to have had adequate training or experience with technology integration, in general, and *GeoGebra*, in specific. This is consistent with other studies that mentioned this factor as the top most cited issue hindering teachers' use of technology (Bingimlas, 2009). Interestingly, despite the fact that the teachers reported not having adequate training, they still indicated that their knowledge and skills were the least inhibiting factors in their technology integration. Teachers' lack of training and competence in technology integration is in fact directly related to their knowledge, skills and confidence (Becta, 2004; Bingimlas, 2009).

Analyzing these results clarifies the interconnectivity among the zones and how it is best to work on all of them simultaneously. This study also highlights the importance of working in teachers' own environments or contexts. In line with this, Goos (2013) conducted a study where the researcher's role was that of a facilitator of change within teachers' zone systems. Goos (2013) maintains that:

> Focusing on the person-in-practice allows for interpretation of knowledge and beliefs within teachers' professional contexts, while refocusing the lens on the practice-in-person shifts attention to identity formation as practice changes the person. (p. 532)

7. Recommendations

The visualization of data on teachers' zones and TPACK stages as it relates to integrating GeoGebra in teachers' practices, in particular, and any other technology in general, can be a good ground for determining the real reasons behind adopting or rejecting technology in teaching. Moreover, this study highlights the importance of considering various individual and contextual factors that impact mathematics teachers' technology integration. It is insufficient to address teachers' needs by tackling only one type of barrier since all the barriers are interconnected. Consequently, better decide how to prepare differentiated professional development. Those professional development modules should cater to teachers' instructional, curricular and pedagogical needs and beliefs, as well as to be coherent with their classroom and school context. In addition, it could point out what type of follow up is needed to insure the change in teachers' TPACK and practices regarding teachers' technology integration.

References

S. Barab and K. Squire (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences*, 13(1), 1–14.

H. Boris, C. Campbell, M. Cavanagh, P. Petocz, and N. Kelly (2013). Technological pedagogical content knowledge of secondary mathematics teachers. *Contemporary Issues in Technology and Teacher Education*, 13(1), 22–40.

British Educational Communications and Technology Agency (Becta). 2004. A review of the research literature on the uptake of ICT of teachers. Retrieved from http://www.becta.org.uk

K. A. Bingimlas (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. *Eurasia Journal of Mathematics, Science and Technology Education*, 5(3), 235–245.

C. S. Chai and J. H. L. Koh (2017). Changing teachers' TPACK and design beliefs through the Scaffolded TPACK Lesson Design Model (STLDM). *Learning: Research and Practice*, 3(2), 114–129.

C.-H. Chen (2008). Why do teachers not practice what they believe regarding technology integration? *The Journal of Educational Research*, 102(1), 65–75.

A. Collins (1992). Toward a design of science education. In E. Scanlon and T. O'Shea (Eds.), *New Directions for Educational Technology* (pp. 15–22). Berlin: Springer Verlag.

A. Doering, S. Koseoglu, C. Scharber, J. Henrickson, and D. Lanegran (2014). Technology integration in K–12 geography education using TPACK as a conceptual model. *Journal of Geography*, 113(6), 223–237.

R. S. Earle (2002). The integration of instructional technology into public education: Promises and challenges. January-February 2002, ET Magazine Website: http://BooksToRead.com/etp.

H. Forgasz (2006). Factors that encourage or inhibit computer use for secondary mathematics teaching. *Journal of Computers in Mathematics and Science Teaching*, 25(1), 77–93.

M. Goos (2005). A sociocultural analysis of the development of pre-service and beginning teachers' pedagogical identities as users of technology. *Journal of Mathematics Teacher Education*, 8, 35–59.

M. Goos (2009). Investigating the professional learning and development of mathematics teacher educators: A theoretical discussion and research agenda. In R. Hunter, B. Bicknell, and T. Burgess (Eds.), *Crossing Divides: Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia* (Vol. 1). Palmerston North, NZ: MERGA.

M. Goos (2013). Sociocultural perspectives in research on and with mathematics teachers: A zone theory approach. *ZDM — Mathematics Education*, 45(4), 521–533.

M. Goos and A. Bennison (2008). Surveying the technology landscape: Teachers' use of technology in secondary mathematics classrooms. *Mathematics Education Research Journal*, 20(3), 102–130.

M. Goos, S. Dole, and K. Makar (2007). Designing professional development to support teachers' learning in complex environments. *Mathematics Teacher Education and Development*, 8, 23–47.

M. Goos, S. Soury-Lavergne, T. Assude, J. Brown, C. Ming Kong, D. Glover… and M. Sinclair (2010). Teachers and teaching: Theoretical perspectives and issues concerning classroom implementation. In C., Hoyles, and J. -b. Lagrange (Eds.), *Mathematics Education and Technology: Rethinking the Terrain* (pp. 311–328). New York: Springer.

M. Heitink, J. Voogt, P. Fisser, L. Verplanken, and J. van Braak (2017). Eliciting teachers' technological pedagogical knowledge. *Australasian Journal of Educational Technology*, 33(3).

K. F. Hew and T. Brush (2006). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, 55, 223–252

H. Kasti (2018). *Effect of a Collaborative and Iterative GeoGebra Module on In-Service Mathematics Secondary Teachers' Zones, Practices, and Technological Pedagogical Content Knowledge*. Lebanese University. ProQuest Dissertations Publishing, 2018. 28261375

M. Koehler and P. Mishra (2008). Introducing TPCK. In J. Colbert, K. Boyd, K. Clark, S. Guan, J. Harris, M. Kelly, and A. Thompson (Eds.), *Handbook of Technological Pedagogical Content Knowledge for Educators* (pp. 3–29). New York, NY: Routledge.

C. P. Lim and M. Khine (2006). Managing teachers' barriers to ICT integration in Singapore schools. *Journal of Technology and Teacher Education*, 14(1), 97–125.

P. Mishra and M. Koehler (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054.

M. L. Niess, R. N. Ronau, K. G. Shafer, S. O. Driskell, S. R. Harper, C. Johnston, C. Browning, S. A. Özgün-Koca, and G. Kersaint (2009). Mathematics teacher TPACK standards and development model. *Contemporary Issues in Technology and Teacher Education*, 9(1), 4–24.

S. Oncu, O. Delialioglu, and C. A. Brown (2008). Critical components for technology integration: How do instructors make decisions? *Journal of Computers in Mathematics and Science Teaching*, 27(1), 19–46.

E. Ottenbreit-leftwich and P. Ertmer (2010). Teacher technology change. How knowledge, beliefs and culture intersect. In *Journal of Research on Technology in Education*.

S. Prediger, A. Bikner-Ahsbahs, and F. Arzarello (2008). Networking strategies and methods for connecting theoretical approaches: First steps towards a conceptual framework. *ZDM*, 40(2), 165–178.

L. Robinson (2009), A Summary of Diffusion of Innovations. Available at: http://www.enablingchange.com.au/Summary_Diffusion_Theory.pdf

E. M. Rogers (1995). *Diffusion of Innovations* (4th ed.). New York: Free Press.

E. M. Rogers (2003). *Diffusion of Innovations* (5th ed.). New York: Free Press.

E. M. Rogers (2011). The diffusion of innovations. In V. Hoffmann (Ed.), *Knowledge and Innovation Management* (pp. 37-50). Retrieved from https://www.uni-hohenheim.de/uploads/tx_uniscripts/25720/A7020_KIM_2011.pdf

L. S. Shulman (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.

E. Sträub (2009). Understanding technology adoption: Theory and future directions for informal learning. *Review of Educational Research*, 79(2), 625–649.

J. Valsiner (1997). *Culture and the Development of Children's Action: A Theory of Human Development*. John Wiley and Sons.

L. Vygotsky (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

F. Wang and M. J. Hannafin (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5–23.