IN-SERVICE MATHEMATICS TEACHERS' INTEGRATION OF ICT AS INNOVATIVE PRACTICE

Wajeeh Daher[1,2] Nimer Baya'a[1] Rawan Anabousy[1]

[1] Al-Qasemi Academic College of Education, Baqa-El-Gharbia, Israel; wajeehdaher@gmail.com

[2] An-Najah National University, Nablus, Palestine

Authors details

Wajeeh Daher:

Affiliations: An-Najah National University, Nablus, Palestine & Al-Qasemi Academic College of Education, Baqa-El-Gharbia, Israel

E-mail: wajeehdaher@gmail.com

Nimer Baya'a:

Affiliations: Al-Qasemi Academic College of Education, Baqa-El-Gharbia, Israel

E-mail: bayaan@qsm.ac.il

Rawan Anabousy

Affiliations: Al-Qasemi Academic College of Education, Baqa-El-Gharbia, Israel

E-mail: rawan.anabosi@gmail.com

Abstract: We describe lower-secondary in-service mathematics teachers' development of ICT integration in their teaching. This is done through the innovation diffusion model of Rogers. In the present research, ICT integration in mathematics teaching is considered an innovation candidate for adoption by mathematics in-service teachers. Five in-service middle school teachers participated in the present research. We used two data collecting tools: observations and semi-structured interviews to collect data about different issues related to the integration of ICT. The categories of the innovation diffusion model were used to analyze the participants' adoption of ICT for their teaching before and after our intervention through the implementation of the Professional Development School model. The research findings indicate that the participating teachers' attitudes and beliefs regarding the benefits of ICT for mathematics teaching were positive at the beginning of the experiment as well as at its end. At the same time, teachers' knowledge and experience of using ICT tools in mathematics teaching improved, which contributed positively to the confirmation of their decision to adopt these tools for their classrooms. Specifically, the research results indicate that the PDS can support the in-service mathematics teachers in their adoption of new innovations.

Keywords: In-service teachers, professional development school, integration of ICT, mathematics teachers

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Introduction

ICT Use in Teaching Mathematics and Obstacles Hindering This Use

Different studies described the benefits of integrating ICT in Education for students (as contributing to the production of knowledge and students' interaction) and teachers (as promoting new pedagogical practices and enhancing teaching). Becta`s (2003) clarifies the contribution of ICT to students' production of knowledge, saying that ICT causes students not only to receive information, but also to provide information themselves. This could be considered an indicator that ICT supports constructivist pedagogy, where pupils use technology to explore and reach the understanding of mathematical concepts, which specifically enhances students' understanding of basic concepts (Kreijns et al., 2013). Becta (2003) also points at the contribution of ICT to students' interaction, saying that ICT enhances and encourages the interaction between students, as well as between students and the technology itself. ICT also contributes to teachers' instruction. Kreijns et al. (2013) claim that ICT can enable, promote, and reinforce the use of new pedagogical practices that correspond with the educational demands of the twenty-first-century knowledge society. In addition, ICT, when combined with authentic activities can contribute to students' positive emotions (Daher, 2011), as well as beliefs about the nature of mathematics (Daher, 2013).

In spite of the ICT benefits described above, teachers are often more reluctant than willing to use information and communication technology (ICT) (Kreijns et al., 2013). Keong, Horani and Daniel (2005) and Jones (2004) identified different barriers to ICT integration: (1) lack of confidence of teachers in using technology; (2) lack of time in the school schedule for projects involving ICT; (3) insufficient teacher training opportunities for ICT projects; (4) inadequate technical support and lack of resources at the school for these projects; (5) lack of teachers' knowledge about ways to integrate ICT to enhance the curriculum; (6) difficulty in integrating and using different ICT tools in a single lesson; (7) unavailability of resources at home for the students to access the necessary educational materials and (8) the age of the teachers, where older teachers are reluctant to use new digital technologies. These barriers explain why teachers could be reluctant to adopt ICT as an innovation in their teaching, and thus, should be taken into consideration when studying teachers' adoption of such innovations. In the present research, we take these barriers into consideration to study five in-service mathematics teachers' adoption of ICT as an innovation in the mathematics classroom. This adoption of ICT as an innovation could be considered as part of the in-service teachers' professional development in ICT.

Teachers' Professional Development in ICT

The integration of ICT has been a key component of the agenda of teachers' professional development, where this agenda is influenced by three elements overlapping with each other to facilitate the use of ICT within schools (Mumtaz, 2000). These elements are: institutions, resources, and teachers, where the main barrier preventing the implementation of technology in education is teachers' confidence, beliefs and attitudes towards the role of technology, and towards the ability of successfully implementing it within schools (Magen-Nagar & Peled, 2013; Thomas & Palmer, 2014). Thus it is important to examine teachers' beliefs towards the integration of ICT in their teaching as a first step towards leading them to integrate ICT in the classroom. As supervisors of mathematics pre-service teachers in the training schools, we consider it our role to encourage the integration of ICT in teaching among the mentoring mathematics teachers in the training schools. This role is founded on our convection that ICT contributes to students' production of mathematical knowledge through supporting them in their mathematical investigations (Kreijns et al., 2013). This role is further based on the comment made by Jaworski and Huang (2014), depending on studies that have explored the relationship between professional development programmes and student performance in mathematics, that an effective professional development programme should include the following characteristics: (I) alignment with shared goals (school, district and state) and assessment; (II) focusing on core content and modelling of teaching strategies for the content; (III) inclusion of opportunities for active learning of new teaching strategies; (IV) provision of opportunities for collaboration among teachers; and (V) inclusion of embedded follow-up and continuous feedback.

As described above, we attempt to encourage in-service mathematics teachers to integrate ICT tools in their mathematics classrooms. In the present research, we try to examine the consequences of one such attempt. We do that utilizing the innovation diffusion model developed by Rogers (2003). In more detail, this examination looks at the development of five mentoring mathematics teachers' beliefs and behaviors regarding the integration of ICT in their teaching in a professional development school (PDS). For us, a PDS is a school in which pre-service teachers, their school mentors and their college supervisors try to professionally develop together. This image of PDS utilizes the framework of community of inquiry of Jaworski (2005), where teachers and researchers/didacticians collaborate to develop professionally.

Community of Inquiry for Professional Development:

Lave and Wenger (1991) consider knowledge as participation in the practice or activity of the community, and not as the individual consciousness of the participants. Nardi (1996) claims that to understand the participant knowledge we need to look not at the individual, nor the environment, but at the interaction between the two. The learning in the community could be looked at as co-learning inquiry (Jaworski, 2008). This co-learning inquiry means that people engage together in knowledge building through inquiry. This view of knowledge as developing in the community describes the processes through which knowledge develops: engagement, imagination and alignment (Wenger, 1998). Jaworski (2008) argues that the terms participation, belonging, engagement and alignment all point towards the situatedness of activity and, as a result, the situatedness of the growth of knowledge in practice. Joworski (ibid) emphasizes that the three previous processes mean that in a community of inquiry, the participants are not satisfied with the desirable state. Instead, they approach their practice with a questioning attitude, with the goal to start to explore alternatives through wondering and asking questions about what else is possible, without the intention to change everything overnight. In our case, the alternative was utilizing digital tools in mathematics teaching. The participating in-service teachers questioned their teaching behaviours as compared with the pre-service teachers' behaviours; those behaviours that were informed by their supervisors' beliefs about ICT tools' roles in mathematics education as well as their advice regarding the utilization of digital tools in the mathematics classroom in the training school. In the present research, we intend to study the in-service teachers' utilization of digital tools in the mathematics classroom through the innovation diffusion model.

Innovation Diffusion Model

Innovation diffusion is the process by which innovation is communicated among the members of a social system through certain channels over time (Rogers, 2003). Moreover, the innovation-decision process is an activity in which information is sought and processed. In this activity, an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation (Sahin, 2006). Moreover, according to Rogers (2003), the innovation diffusion process passes over time through five stages (1) knowledge of an innovation, (2) forming an attitude toward the innovation, (3) taking a decision to adopt or reject, (4) implementation of the new idea, and (5) confirmation of the decision by affirming or rejecting it. In the present research, we intend to examine, using Rogers' model of innovation diffusion, the development of ICT integration by in-service mathematics teachers working in a PDS.

The innovation diffusion model utilizes several educational constructs in which mathematics education researchers have been studying in frame of their study of mathematics teachers' practices and professional development. These constructs include teachers' beliefs and decisions.

Teachers' Beliefs and Decisions

Schoenfeld (1998) links teachers' decisions to their beliefs by arguing that teachers' knowledge, goals and beliefs influence their decision-making in the mathematics classroom. Moreover, teachers' beliefs have mutual relationship with their interactions with their students (Richardson, 1996; Voss, Kleickmann, Kunter & Hachfeld, 2011). Specifically, Barkatsas and Malone (2005) found that teachers' beliefs impact their practices. On the other hand, several researchers claim that beliefs are but one aspect that influence teachers' practice including their interaction with their students. Other aspects are teachers' knowledge and attitudes (Remillard & Bryans, 2004; Schoenfeld, 2008).

Hannula, Opt'Eynde, Schlöglmann and Wedege (2007) describe factors of mathematics teachers' beliefs as agreed upon by Rösken, Hannula, Pehkonen, Kaasila and Laine (2007), as well as by Diego-Mantecón, Andrews and Op 't Eynde (2007): Beliefs about mathematics (e.g. difficulty, enjoyment), beliefs about the self (e.g., goal orientations, relevance, self-efficacy), and beliefs about the classroom context (e.g. teacher's role).

As to teachers' decisions, teachers' decision-making and lesson-practice are interrelated (Bosse & Törner, 2012; Hobbs, 2012). Researchers have attempted to characterize the factors that affect teachers' decisions to use technology in their teaching, and how these decisions affect their practice. For example, Daher and Baya'a (2014) studied teachers' decisions to use mobile learning in the mathematics classroom, and found that different factors have an impact on teachers' decisions regarding the use of mobile learning in the mathematical lessons. The factors include the teacher's history of using technologies in teaching; the teacher's perceptions of using technologies in teaching; the school community, including the principal and the coordinating teacher; rules regulating the use of technologies in teaching mathematics; and division of labor regarding this use, as who should prepare the learning activities needed to be used for learning mathematics with the mobile phone.

Research methodology

In the present research, we report the development of the integration of ICT by five lower-secondary in-service mathematics teachers in a professional development school (PDS) because of their mentoring of mathematics pre-service teachers during one academic year.

Our pre-service teachers are trained specifically to use visual dynamic tools to investigate with their students questions that encourage higher order cognitive skills, such as: 'Would the three perpendiculars in a triangle meet at the same point? If so, what could you say about the location of that point?' They would help their students phrase conjectures and discuss using mathematical reasoning the correctness and justification of these conjectures. The mentoring teachers are encouraged to use the visual dynamic tools by themselves in order to encourage their students' conjecturing and justification of mathematical relations.

To encourage the in-service teachers to integrate technology, the following methods were employed: watching video clips of past-years pre-service teachers during integrating technology in their mathematics teaching, preparing ICT-based mathematics lessons together with the pre-service teachers, watching the present pre-service teachers teach ICT-based mathematics lessons, teach together with the pre-service teachers ICT-based mathematics lessons, and teach with the support of pre-service teachers ICT-based mathematics lessons.

Data Collecting and Analysing Tools

We used two collecting tools: observations and semi-structured interviews to collect data about different issues related to the integration of ICT in the lessons of the participating in-service teachers. In more detail, we used semi-structured interviews to collect data about the participating in-service teachers' beliefs and knowledge regarding the ICT integration in mathematics teaching at the beginning and end of the academic year. At the same time, we used observations to assess their actual integration.

To analyze the data, we used the innovation diffusion model (Rogers, 2003) in order to categorize the in-service teachers' beliefs and practices of the integration of ICT into mathematics teaching. Doing so, we identified factors that could affect the innovation diffusion in each stage regarding the in-service teachers' use of ICT in teaching mathematics. These stages were: knowledge (when the participants learned about ICT use in mathematics teaching), persuasion (when they were persuaded of the value of ICT use in mathematics teaching), decision (when they decided to adopt ICT use), implementation (when actually integrating ICT in the classroom), and confirmation (when the integration was affirmed).

ICT Tools Utilized By the Mentoring Teachers:

Our pre-service teachers are required, in their third year of study, to integrate ICT in their practice as mathematics teacher trainees in the training schools. In this integration they are requested to use various ICT tools and technological pedagogical models which they were introduced to and discussed in the didactics courses. Examples of such tools and models include: Videos and presentations; digital worksheets and games; spreadsheets, applets and GeoGebrea; applications of cellular phones; Wiki, Google Docs and Sites; and social networking sites such as Facebook. The mentoring teachers were encouraged by the pre-service teachers' supervisors to use the same ICT tools in their teaching of mathematics.

Findings

We present the in-service teachers' knowledge, experience, obstacles and beliefs at the beginning of the academic year, then the other stages and afterwards we present again their knowledge, experience, obstacles and beliefs at the end of the academic year.

Teachers' Knowledge, Experience, Obstacles and Beliefs at the Beginning of the Academic Year

At the beginning of the initiative, we, as supervisors of pre-service teachers in a PDS, faced some difficulties and obstacles convincing the mentoring teachers to integrate technology in mathematics teaching. One reason for the existence of these difficulties is the moderate knowledge possessed by the participating teachers in ICT. In more detail, the participating teachers reported that generally they were acquainted with some Office programs, like Word and PowerPoint, and with the Internet. The difficulties and obstacles were due also to the little experience of the participating teachers in integrating ICT in their mathematics teaching. For example one teacher reported using ICT infrequently for one year, while another teacher reported using only PowerPoint presentations and sometimes online games.

Together with the moderate knowledge in ICT and the little experience of the participating teachers in integrating ICT in their mathematics teaching, they were confronting different types of obstacles that discouraged them from integrating ICT in the classroom. These obstacles were of the types: Logistic obstacles (Insufficient infrastructure, students' density in the classroom, insufficient number of lessons), technology knowledge obstacles (fear to use technological tools), and technological pedagogical content knowledge obstacles (need for pedagogical support in integrating technology in the specific mathematical topics).

In spite of the participating teachers' little experience in integrating ICT in their teaching and the obstacles that they confronted and discouraged them to integrate ICT in the classroom, the participating teachers had positive beliefs about the ICT integration in mathematics teaching. These positive beliefs were expressed through talking about the advantages of ICT integration in mathematics teaching: Advantages related to the learning materials (Connecting mathematics with real life phenomena, embodiment and visualization of mathematical concepts, manipulation of the mathematical objects), advantages related to the learner (contribution to the learner's cognitive skills, contribution to the learner's technical skills, contribution to the learner's imagination skills, bridging the gap between students, bridging the gap between students and the teacher), and advantages related to the teacher (providing tools that assist the instruction, contribution to the material coverage, explaining the content).

These mentoring teachers' beliefs about the use of technology in the mathematics classroom were probably due to the general atmosphere regarding the importance of technology in education. This general atmosphere consisted in the atmosphere across schools, as well as in the school itself. The mentoring teachers' beliefs were also due to their preparation as pre-service teachers, where this preparation includes at least two courses in ICT integration in teaching. In spite of the participating teachers' positive beliefs, they were reluctant to integrate technology in mathematics education due, as mentioned before, to their little experience to do so and to the obstacles of different types that they were confronting in doing so.

Persuasion, Decision and Adoption

The five participating teachers agreed to mentor the pre-service teachers in their attempt to integrate ICT in their teaching. Nevertheless, they were afraid to integrate by themselves ICT in their teaching. We guaranteed the collaboration of our pre-service teachers with them and promised to accompany them in their integration of ICT in their teaching. This made them more convinced to accompany our pre-service teachers in their integration of ICT in mathematics teaching; what resulted in their decision to participate in the experiment. In the interview, the mentoring teachers emphasised the importance of the support given by the pre-service teachers' supervisors to the mentoring teachers and to the pre-service teachers. They said that this support gave them confidence to practise using ICT tools in their teaching of mathematics. Overall, it could be said that all the participating teachers adopted our initiative; i.e. using ICT in mathematics teaching, but in different levels.

Implementation: Knowledge, Experience and Obstacles

The mentoring teachers reported that their experience of accompanying the pre-service teachers in integrating technology in teaching mathematics added to their knowledge regarding technology itself, as well as its integration, and encouraged them themselves to integrate technology into their own teaching. This accompanying, they said, made their integration of technology into their own teaching easier and enjoyable. More specifically, three domains of pre-service teachers' assistance were pointed at by the mentoring teachers: technical assistance (for example helping in drawing functions using GeoGebra), technological pedagogical content assistance (for example helping in building technological models using GeoGebra for teaching specific mathematical topics), and affective assistance (for example showing understanding for the difficulties which the mentoring teachers encounter).

In addition, the mentoring teachers' experiences also included tackling logistic and technical obstacles while integrating technology in their teaching, but they looked at these obstacles as a natural part of engaging with ICT in teaching.

Confirmation: In-Service Teachers' Beliefs and Intentions at the End of the Academic Year

At the end of the experiment, the mentoring teachers had the same positive beliefs about integrating technology in the mathematics classroom, but now these beliefs seemed to be founded on their experiences and not only on their previous studies and the general atmosphere regarding the importance of ICT in education, especially in mathematics eduction. Moreover, the mentoring teachers became more knowledgeable regarding what to do with ICT in the mathematics lessons.

Regarding their intentions to use ICT in their teaching, the mentoring teachers expressed their intention to integrate ICT in their future teaching of mathematics, but as an additional tool in the mathematics classroom, and not all the time. For example one mentoring teacher said that GeoGebra is best for students to investigate mathematical relations, but the pencil and paper are needed for the students to assimilate and improve their procedural and formal mathematical skills.

Discussion

The in-service mathematics teachers who participated in the research had at the beginning positive beliefs about the contribution of digital tools to mathematics teaching. Furthermore, being part of a PDS, these participating teachers substantiated with classroom-evidence their starting beliefs regarding the integration of technology in the mathematics classroom. The pre-service teachers' initiatives and experiences in teaching mathematics with ICT constituted the first phase of this evidence witnessed by the in-service teachers, but soon the evidence came from the in-service teachers' own experiences of integrating ICT in their mathematics teaching. The development of the in-service mathematics teachers' beliefs and practices regarding the integration of ICT in their teaching would probably not happened without the PDS, for it helped create a community of teaching professionals that encouraged certain teaching behaviors (including integrating ICT in mathematics teaching and learning) and substantiated beliefs regarding these behaviours (Jaworski, 2008). The PDS was optimal for the in-service teachers to substantiate their positive beliefs about the integration of ICT in their teaching. This is due to the fact that in this context, it is possible for the in-service teachers to experiment teaching behaviors, and thus decide whether to adopt these behaviors or not. It could be claimed that the PDS in which the in-service teachers, the pre-service teachers and the researchers were part of, was effective due to the charateristics of the PDS that included appropriate context (as supporting professional development and the changes it is intended to bring about), approprite content (as sharpening the participants' classroom skills), and appropriate process (as supporting interaction among the participants) (Harwell, 2003). Furthermore, this PDS was effective for it included the factor of shared vision among all the participants in the PDS and which is need for the success of the PDS (Lynch-Davis, Salinas, Crocker & Mawhinney, 2015). This shared vision was there from the beginning, but the practices of the PDS strengthened it.

This positive influence of the PDS on the educational scene is described by researchers; for example by Cave and Brown (2010) regarding the positive influence on students' achievement, and by Boote (2014) regarding the positive influence on mathematics pre-service teachers’ emerging pedagogical content knowledge. The present research found that the PDS has positive influence on mathematics in-service teachers' practices; specifically on their adoption of new innovations. It should be emphasized that the PDS paved the way to the successful work of a community of inquiry that had the goal of advancing the utilization of digital tools in the mathematics classroom.

The theory of the community of inquiry or practice (Wenger, 1998) utilized above to explain the PDS effect on the participating in-service teachers' utilization of ICT tools in their classrooms could be further utilized to connect the concept of identity to the concept of practice. In the present research, the in-service teachers were part of a community of practice, where the identity of the in-service teachers moved towards closing the gap between the actual identity and that designated by the researchers through experimenting with the pre-service teachers. It seems that the identity of the in-service teachers reached equilibrium, regarding their use of ICT in their teaching of mathematics. This equilibrium was between their actual identity before the experiment and that designated by the researchers. Closing the gap or reaching an equilibrium between the actual and the designated identity of teachers indicates that the in-service teachers underwent professional development; in other words learning (Sfard & Prusak, 2005).

Conclusions

The PDS could serve as a platform for social learning in a community of practice/inquiry with the goal of utilizing digital tools for teaching, in our case mathematics teaching. This social learning has assumptions that differ from those made in the common theoretical frameworks of teachers’ competencies and professional development (Bosse & Törner, 2015). Programmes of professional development of mathematics teachers that emphasise the utilization of ICT tools in the mathematics classrooms can benefit when following this model of social learning in a community of inquiry in which researchers, in-service teachers and pre-service teachers learn together to find the best ways for utilizing digital tools in the mathematics classroom.

Future research could study the relationship between pre-service teachers' adoption of digital tools for mathematics teaching and their mentoring in-service teachers' adoption of these tools for this teaching. Such research could be qualitative or quantitative or combined.

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