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Implementation enterprise through the lens of a theory of diffusion of innovations: A case of online problem-solving forums

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The goal of this article is to present and theorize our more successful and less successful attempts to create and sustain problem-solving forums, in which exploratory discourse takes place. The main argument is that many implementation-related phenomena that we have encountered when working with seven high-school classes for one or two school years can be characterized and explained with the aid of conceptual tools provided by Rogers' Theory of Diffusion of Innovation. The most successful process of forming an online forum in one of the classes is presented in some detail, and the parallel processes in the rest of the classes are presented in the form of an aggregated summary. Implications for future design-based implementation research are drawn.

Keywords: Problem solving, online forums in social networks, diffusion of innovations.

Introduction

This article presents an implementation aspect of a research project entitled “Heuristic and engagement aspects of learning through long-term collaborative mathematical problem solving”¹. The main research goal of the project (on-going until September 2017) is to produce a model of learning through mathematical problem solving, which would be attentive to cognitive, socio-affective and contextual aspects of this activity. In particular, the model is supposed to attend to interactions between variations in heuristic behaviors (Koichu, Berman & Moore, 2006; Koichu, 2010) and socio-affective engagement structures (Goldin et al., 2011) activated when high-school students collaboratively cope with challenging mathematics problems for relatively long time.

An implementation aspect of the project consists of designing and sustaining a special learning environment, in which long-term problem solving might be investigated. The intended environment comprised of a particular combination of problem-solving lessons in a classroom and out-of-classroom work supported by online asynchronous discussion forums. Its design was strongly informed by past research on affordances of online learning environments. Past research tells us that students in online environments can actively participate in solving complex problems for 2-3 weeks almost without teacher interventions (Moss & Beatty, 2006) and that some of those students who tend to be silent in a classroom can actively participate in online discussions (Schwarz & Asterhan, 2011). In addition, there is evidence that online discussions enable students to meaningfully use their mathematical knowledge, enhance self-regulation skills and support knowledge construction (Nason & Woodruff, 2003; Tarja-Ritta & Järvelä, 2005; Stahl, 2009).

Schwarz and Asterhan (2011) attribute the benefits of online discussions to their unique traits, such as: fostering divergent rather than linear interactions, enabling flexible time schedules of

¹ Selected findings of the project are reported in Lachmy & Koichu (2014), Koichu (2015ab), Keller and Koichu (in press).

participation in the discussions over relatively long periods of time, encouraging explicit and accurate expression of the ideas in writing. Koichu (2015ab) argues that many affordances of an online problem-solving forum stem from its fundamental characteristics of being a *choice-affluent environment*, that is, an environment, in which the students are empowered to make informed choices of: a challenge to be dealt with, a way of dealing with the challenge, a mode of interaction, an extent of collaboration, and an agent to learn from. In brief, past research on online collaborative problem solving presents many evidence-based cases of successfully working online forums.

However, little is known from the professional literature about how to put the forums into work and sustain them. Our experience in the aforementioned project taught us that this enterprise is truly challenging. The goal of this article is to make sense and theorize our more successful and less successful attempts to create and sustain problem-solving forums, in which exploratory rather than expository problem-solving discourse (this distinction is due to Stahl, 2009) takes place. The main argument is that many implementation-related phenomena that we have encountered when working with seven high-school classes (grades 10 and 11) can be characterized and explained with the aid of conceptual tools provided by Roger's (2003) Theory of Diffusion of Innovation.

Conceptual framework

Approach: Design-Based Implementation Research (DBIR)

Werner (2004) refers to *implementation research* as the systematic study of the implementation of innovations. Fishman, Penuel, Allen, Cheng and Sabelli (2013) point out that this type of research encompasses studies of fidelity, of variations in implementations as well as studies of conditions under which programs can be implemented effectively. They further refer to implementation research and to design-based research as antecedents of a new, emerging research model, which they name Design-Based Implementation Research (DBIR). The core principles of DBIR are as follows:

- (1) a focus on persistent problems of practice from multiple stakeholders' perspectives; (2) a commitment to iterative, collaborative design; (3) a concern with developing theory and knowledge related to both classroom learning and implementation through systematic inquiry; and (4) a concern with developing capacity for sustaining change in systems. (Fishman, Penuel, Allen, Cheng and Sabelli, 2013, pp. 136-137)

In addition, DBIR calls for breaking down barriers that isolate those who design and study innovations and those who study the diffusion of innovations. We find the DBIR concept and principles well-adjusted to the needs of our project.

Vocabulary: Selected elements of the theory of diffusion of innovations

The notion *innovation* is frequently used in the literature on implementation research as a self-explanatory one (Fishman et al., 2013). However, there exists a branch of the professional literature that explicitly focuses on innovations and the processes of their diffusion. In particular, Rodgers (2003) defines *innovation* as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption. It matters little, so far as human behavior is concerned, whether or not an idea is 'objectively' new as measured by the lapse of time since its first use or discovery" (p. 11). In our case, the idea of stretching the boundaries of a classroom by means of an online problem-solving forum was an innovation because it was new to the students and the teachers.

Rodger's (2003) theory of diffusion of innovations meticulously characterizes the *innovation-decision process*, in which individuals (or other decision-making units) decide whether to accept an innovation or not. In particular, Rodgers distinguishes five stages of the process: *knowledge*, *persuasion*, *decision*, *implementation* and *confirmation*. The stages are briefly presented below.

At the *knowledge* stage, potential innovation adopters are exposed to the innovation's existence and obtain some information about how it functions. Sometimes individuals become aware of an innovation by accident, and sometimes they actively look for it in order to fulfill particular needs. It is also possible that the needs are formed as a result of one's exposure to an innovation.

At the *persuasion* stage, an individual forms a favorable or unfavorable attitude towards an innovation. This stage presumes affective involvement with the innovation. In particular, the individuals may mentally apply the new idea to their present or anticipated future situation. They seek to answer such questions as "what are the innovation's advantages and disadvantages in my situation?", and seek the answer mostly from their near-peers, whose opinions based on their personal engagement with an innovation, are the most convincing. There is a discrepancy between forming a favorable attitude towards an innovation and an actual decision to adopt it. Adoption of an innovation can be influenced by a *cue-to-action*, an event that crystallizes an attitude into overt behavioral change.

At the *decision* stage, an individual adopts (i.e., makes full use) or rejects an innovation. Any decision is not final however. The rejection can occur even after a prior decision to adopt; in Rodgers' terms, this phenomenon is called *discontinuance*. The theory distinguishes between *active* and *passive rejection*. The former type of rejection consists of considering adoption of the innovation and then deciding not to adopt it. The latter one consists of never "really" considering the use of the innovation. The decision stage frequently includes a small-scope trial. The actual sequencing of the three stages presented so far can alter. Namely, both *knowledge-persuasion-decision* and *knowledge-decision-persuasion* sequences are possible.

At the *implementation* stage, an individual puts an innovation into systematic use. Even though the decision has been made, the adopters may still feel a certain degree of uncertainty about the consequences of the innovation. In addition, problems of how exactly to use the innovation may emerge. Sometimes the adopters change or modify (in Rodgers' terms, *re-invent*) the innovation at this stage. The implementation stage can be lengthy, but it ends when the idea that has once been innovative becomes institutionalized and regularized in the adopters' normal functioning.

Finally, at the *confirmation* stage, an individual constantly seeks reinforcement for the decision to adopt or reject an innovation that has already been made. As a result of positive or negative messages about the innovation, the decision can be reversed. Rodgers points out that the *change agents* (i.e., those who influenced one's decision to adopt an innovation) have responsibility of providing supportive messages to the individuals who have previously adopted the innovation.

Methodological aspects of the project

Participants and the project's activity

Two experienced mathematics teachers and two of their 10th grade classes took part in the first year of the project (2013-2014); five more teachers and their corresponding five classes joined the

project during its second year (2014-2015). Each participating teacher acted in the project as a member of the research group and took part in the meetings of the group. In addition, each teacher worked in contact with an additional member of the group who was responsible for the technological support and documentation of the activity. Mathematics in all participating classes was studied for five hours a week, in accordance with the Israeli high-level curriculum (see Leikin & Berman, 2016, for details). For the concerns of this article, it is enough to mention that geometry was studied two hours a week and that its study included systematic work on proving tasks.

We planned that each participating in the project class would be engaged, at least three times during a school year, in the following activity. The students cope with a series of preparatory tasks during a 90-minute lesson and are offered an especially challenging geometry problem at the end of the lesson. They then engage, for 5-10 days, in solving the problem from home in a closed (that is, available only to the students of a participating class and the members of the research group) online forum. Different technological platforms, including Google+ and WhatsApp, were tried in different classes. When the problem is solved or, alternatively, when the students give up, a 90-minute lesson is conducted in the classroom in order to get closure. The lesson consists of whole-class and small-group discussions, during which the students share their experiences with the problem.

Documentation of the project

Forty-two meetings of the research group were audiotaped (about 100 hours) and, in addition, documented in the protocols of the meetings (more than 100 pages). The documents produced by the group and all relevant email exchange were stored. Every member of the group was required to keep a diary. The diaries were for writing anything their authors deemed important for the project, including their thoughts and feelings in relation to the project's events. The diaries were stored in shared Google Drive of the group and were available for reading and commenting by the members. In addition, 14 lessons were videotaped, the content of the forums was stored (more than 3000 posts), interviews with students and teachers were conducted (about 15 interviews), and the students' written feedback on different aspects of the project was collected.

The story of NK's class, which is presented below in some detail, is produced using *narrative inquiry methodological tradition*. As Clandinin and Caine (2008) explain, "Narrative inquiry is marked by its emphasis on relational engagement between researcher and research participants" (p. 542). This approach was chosen because we (hereafter, BK and NK) had been active members of the processes under exploration; in particular, NK was a mathematics teacher of the class. An aggregated summary of the stories in the rest of the classes is produced using a *general inductive approach* (Thomas, 2006), which enables researchers "to condense extensive and varied raw text data into a brief summary format" (p. 238).

Findings

A (success) story of NK's class

The main events at the *knowledge* phase of the project in NK's class consisted of: (1) a conversation between NK and BK following BK's observation of one of NK's lessons; (2) a conversation between NK and her students. Because of the first conversation, NK decided to take part in the project mainly because the idea to stretch the boundaries of a classroom by means of an online forum resonated well with NK's constant need to enrich her teaching repertoire in order to create

valuable learning opportunities for her students. In Rodgers' terms, NK acted as a *venturesome innovator* who is able to cope with high degree of uncertainty about an innovation, and BK acted as a *change agent*. In her conversation with the students, NK acted as a *change agent*, and the students were potential innovation-adopters to be *persuaded*. NK argued that developing problem-solving skills was a strong benefit of participating in the project, and appealed to the students' curiosity to try something new and be a part of an interesting initiative. The students' reaction to the information about the project was favorable, though not exactly for the reasons that NK had presented.

The first mathematical problem of the project is presented in Figure 1. It is representative of most of the problems of the project. In particular, it looked similar to geometry problems the students were familiar with from classwork and homework. As such, the problem "invited" the students to approach it by means of mathematical ideas that worked well in the past. For instance, the students might think of including the angles, whose equality is to be proved, in a pair of triangles and attempt proving their congruence by finding some equal elements. However, such a general plan was insufficient; something else (e.g., a clever auxiliary construction) should have been invented.

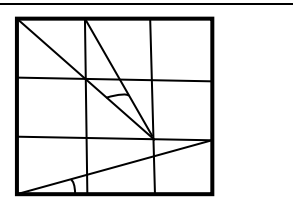
<p>Nine-Square Problem: There is a net of nine congruent squares (see the drawing). Prove that the two angles denoted in the drawing are equal.</p>	
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Figure 1: The first problem of the project

When the problem was uploaded to the Google+ forum, three students worked on it. Their three-hour-long brainstorming session was unsuccessful. As a result, the forum was non-active during the next two days. The following day NK met the students at school and asked: "Why did you stop solving the problem? It is not too difficult". The students showed NK their hand-made drafts as evidence that they had tried. NK asked the students to upload their drafts to the forum and continue solving the problem together. That evening eight students entered the forum, cooperated and eventually solved the problem. Two solutions to the problem by the active participants of the forum and an additional solution by a student who was a silent observer were presented at the mathematics lesson following the forum. The students' voluntarily expressed their suggestions as to how to further run and improve the forum by the end of the lesson,

In Rodgers' terms, the first three students acted as *venturesome innovators*. Rodgers points out that this category of adopters is important for launching a new idea, but they have little influence on other individuals' decision to adopt or reject the idea. The conversation between NK and the students in school was crucially important as a *cue-to-action* for eight students, who acted as *early adopters*. Rodgers characterized this category of individuals as *respectable*, that is, well-integrated members of a local community whose opinion about the innovation matters for the potential adopters. The mathematics lesson, in which these eight students shared their positive experience at the forum with the rest of the class, was another crucially important *cue-to-action*.

The next two problems of the project were approached on the forum by about the same group of students. The students learned to share their half-baked ideas, and even developed some rules related to publishing the full solutions at the forum. In brief, they agreed that a student who obtained

the full solution should not publish it early, in order to not “spoil the fun” for others. The forum was indeed exploratory rather expository in nature. Three months later, collaborative problem solving at the forum became a well-established practice for six students; most of their classmates joined the forum occasionally and constituted the *early majority*. It seems that each student has *decided* how and to which extent to use the forum. The *implementation* stage (three to eight months from the beginning of the project) was characterized by gradual two-directional diffusion of social and socio-mathematical norms developed in the forum and in the lessons. In particular, there were several forum-like lessons initiated by the students (see Keller & Koichu, in press, for details).

The evidence of *confirmation* of the students’ decision to adopt the innovation came from the following sequence of events. As mentioned, the Google+ forum flourished for several months, but it we have not yet mentioned that then it was deserted. NK inquired with the students about this fact and discovered that the activity moved from the Google+ to WhatsApp, a popular social network in Israel since about 2014. The students granted NK access to their WhatsApp forum, and we were happy to find there many autonomous problem-solving discussions of exploratory nature. The WhatsApp forum flourished in NK’s classroom until the students’ graduation in 2016.

An aggregated summary of seven stories

An aggregated summary of the conduct of the project in all participating classes, by Rodgers’ phases, is presented in Table 1.

	NK class	AP class	AH class	ES class	RN class	OG class	LA class
<i>Knowledge</i>	++	++	++	++	++	++	++
<i>Persuasion</i>	++	++	++	++	++	-	+
<i>Decision</i>	Accept	Passive R	Accept	Passive R	Accept		Active R
<i>Implementation</i>	++	+	++	+	+		
<i>Confirmation</i>	++						

Table 1: The implemented stages of the project in seven classes

The sign “++” in the table means that the stage is fully realized; “+” means that the stage is partially realized (e.g., the forum was active only as a trial or only few students were active); “-” means that there were no conditions for realizing the stage; “Active R” and “Passive R” stand for active and passive rejection, respectively. An empty cell means that the project did not arrive at that stage.

As Table 1 tells us, only NK’s class went through all five stages, up to the point when using the online forums for problem solving stopped being an innovation and became a routine. Implementation of the project’s idea at the scope comparative to NK’ class occurred in one other class, and partial implementation – in three classes. In two classes the project did not reach the implementation stage, despite of much effort made by the teachers and the research team.

Concluding remarks

Recalling Tolstoy’s seminal assertion, *happy families are all alike; every unhappy family is unhappy in its own way*, we can argue that there is a unique story behind each cell of Table 1.

Unfortunately, we cannot tell these stories here due to the space constraints. In brief, sometimes school conditions or classroom norms were inappropriate for realizing the project's idea, sometimes a particular *cue-to-action* event did not happen at the right time or was not appropriately designed, and sometimes our decisions and actions as a research group were far from being optimal. We have also observed, more than once, the phenomena of *discontinuance* and of *passive rejection* for which we do not have convincing explanations, despite the extended data set in our possession.

We intend to continue the aforementioned project, and one of the lessons learned so far is that the DBIR concept and theories like the Rodgers' theory of diffusion of innovation should be taken seriously. Either detailed or aggregative analysis of implementation of the project idea is helpful for us as a tool for refining the roadmap of the project. In addition, we now better understand that creating conditions for implementation of an innovative pedagogical idea in a school reality should be given full attention prior to delving into a pursuit for "traditional" research questions, such as questions on cognition and affect in mathematical problem solving that have been the main *research* questions of the project. Based on the accumulated experience, we call for reporting and analysing not only those cases where an innovative idea is being fully implemented, but also those case where the implementation was partial or did not occur as planned. We conclude by suggesting that systematic attention to implementation issues, by means of DBIR, may have not only practical, but also fundamental theoretical significance in mathematics education.

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