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► **To cite this version:**

Nelly Keller, Zehavit Kohen. Teachers' development of self-regulation and problem solving skills in online forums as learners and mentors. Twelfth Congress of the European Society for Research in Mathematics Education (CERME12), Feb 2022, Bolzano (en ligne), Italy. hal-03744719

HAL Id: hal-03744719

<https://hal.science/hal-03744719v1>

Submitted on 3 Aug 2022

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Teachers' development of self-regulation and problem solving skills in online forums as learners and mentors

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The current study explores the learning processes occurring in online discussion forums, from a perspective of self-regulation learning which facilitates in planning, monitoring and reflecting on learning. Participants were 47 teachers, who took part in a 2-year mathematics teachers professional development program. The study was conducted in two stages. In the first stage the teachers acted as learners through collaborative solution of complex mathematical problems in small groups, while in the second stage they led collaborative problem solving in forums as mentors. The study showed that problem solving forums have a high potential for developing teachers' own self-regulation skills and increasing their effectiveness in collaborative problem solving. This experience is reflected in their pedagogical activities, aimed at developing self-regulation skills of their students. It also empowers teachers to support students in solving complex mathematical problems.

Keywords: Problem solving, online forums in social networks, self-regulated learning, professional development of teachers.

Introduction

Currently, the mathematical community has largely reached a consensus on the importance of mathematics problem-solving (PS) as a central goal for mathematics teachers. Mathematics problem-solving involves active role of students, which are involved in a discussion with each other for solving the mathematical problem. Technology allows the application of such collaborative mathematical problem-solving through the use of Problem-Solving Forums (PSF). Studies of the effectiveness of PSF for teaching mathematics has shown that PSF has great teaching potential due to a number of key features such as a shared discussion space, opportunity for asynchrony communication, or preservation of the content of the discussion for a long time. The virtual property of PSF significantly expands the boundaries of classroom both in the space and in time (Kramarski, 2012). Studies show that over time, students participating in PSF develop norms of collaboration, the most important of which is the habit of sharing the ideas in the process of solving problems, rather than publishing the final result or the complete solution (Koichu & Keller, 2019). However, research has shown that realizing the potential of discussion forums is challenging (Koichu & Keller, 2019). One of the main reasons for these difficulties, according to the literature, is the lack of skills in non-traditional forms of education for both teachers and students (Kilpatrick, 2016; Lester & Cai, 2016; Schoenfeld, 2013).

Participation in PSF requires students to be motivated, able to plan, track ideas and results, and reflect on the work done. All of these skills are key components of Self-Regulatory Learning (SRL) (Pintrich, 2000; Zimmerman, 2000). Thus, the effectiveness of the learning process, which includes PSF as an integral part, requires the teacher to use teaching methods that focus on the development of SRL skills and use them in collaborative problem solving (Hogan, et al., 2015). A number of studies have shown that one of the priority ways for teachers to acquire the skills needed to successfully implement new methods is to first test those methods on themselves as learners (e.g. Kramarski & Kohen, 2017).

Specifically, it was found that projects aimed at developing SRL skills in teachers also develop their pedagogical skills focused on developing SRL skills among their students. This approach to education has been called self-regulated teaching (SRT) (Kramarski & Kohen, 2017; Kramarski & Michalsky, 2009). The purpose of this study is to study the processes of forming SRL and SRT skills among teachers who participate in PSF, first in the role of learners, and then in the role of mentors.

Theoretical framework

Collaborative mathematics problem solving

In recent years, collaborative problem solving in small groups as form of learning based on problem solving has been widely studied. Proponents of this method argue that it is based on mathematical discourse that fosters mathematical thinking (Hogar & Harney, 2014; Shindler & Bakker, 2020). The effectiveness of group work largely depends on the type of interactions between its participants (Carlson, & Bloom, 2005). Clark and colleagues have suggested a taxonomy of interactions in the process of collaborative problem solving in two dimensions. The first of these are questions directed to another member or the whole group, such as questions to clarify or define the group's status in moving towards an intended goal. The second-dimension concerns group synergy, which the authors define as long-term collaboration in which participants continue and develop each other's ideas. According to the researchers, the group progresses in learning when group synergy is the most significant interaction in its activities (Clark, et al., 2014). Modern technologies allow using online forums in social networks as one of the possible platforms for collaborative solving of math problems in small groups. This is possible due to the characteristics of online forums as having a common space for discussion, asynchrony, preservation of discussion content and virtuality.

Self-Regulated Learning (SRL)

In this study, SRL is defined according to Pitrich and Zimmerman, as a cyclic recursive process combining motivational, cognitive and meta-cognitive components (Pitrich, 2000; Zimmerman, 2000). In this definition, cognition refers to direct mathematical actions aimed at solving a problem; meta-cognition refers to the ability to understand and control cognitive processes, and motivation refers to the student's attitude to his/her abilities to solve a problem. According to Schoenfeld (2013), the meta-cognitive aspect – including the ability to plan, monitor and reflect on the work done – is especially important for the successful solution of mathematical problems. To successfully tackle complex challenges in collaborative learning, in addition to each student's SRL, meta-cognitive collaboration is required, where team members or groups act as a unit, defining common goals and choosing common strategies (e.g. Hogar & Harney, 2014). Research shows that SRL skills are not acquired spontaneously. Their development requires an environment, targeted learning, and guidance referred to as Self-Regulated Teaching (SRT) (Kramarski & Michalsky, 2009).

Many studies point out the need of developing advanced training programs for mathematics teachers, that will help them develop the SRL skills of their students (Hoover et al., 2016; Kramarski & Michalsky, 2009). In recent years, a theory of the teacher's dual role in the acquisition of SRL skills has been developed. The theory has proven the effectivity of developing SRL skills in teachers, to increase their ability to develop these skills in students (e.g., Kramarski & Kohen, 2017). Research on teacher professional development (PD) in online environment, which has become widespread in

the past few years, has shown that the online environment has a positive effect on the development of teacher skills in SRL (e.g., Broadbent et al., 2021).

Research questions (RQs) are: a) How do teachers' SRL and collaborative PS skills evolve during their continued participation in PSF as learners? and b) How are the teachers' SRL and PS skills reflected in leading a PSF as mentors?

Methodology

The study took place in two stages. At the first stage, within the framework of the course "Fundamentals of Geometry: Plane Transformations", each teacher participated in six PSF meetings as a learner in a group of four. Each meeting was devoted to joint discussion and solution of a complex geometric problem. At the second stage, within the framework of the course "Methods of teaching mathematics", each of the participants acted as a mentor (teacher) in two forums, where students, under their guidance, also solved complex geometric problems. Throughout the study, teachers received targeted SRL support by the facilitator of the PD program, through collaborative discussions on forum processes, and guidelines during the forums themselves.

Participants and research background

The study was conducted as part of a 2-year Mathematics Teacher PD Program at the Faculty of Education in Science and Technology at the Technion, Israel. The program aims at expanding the mathematical and pedagogical knowledge and skills of teachers, for the goal of reaching a teaching license that will enable them to teach all levels of mathematics. The study involved 47 teachers with 5 to 15 years of experience, teaching in high schools in the north of the country. This paper focuses on the activity of one of the teachers, named John. John (35 years old) is a math teacher at a school in the north of Israel with 12 years of experience. John was selected as a case study for two reasons. On the one hand, his activity in the forums in which he acted as a learner, which was evaluated by the number of statements he posed, was similar to the average number of statements posed by the entire group of teachers. On the other hand, John's example shows clear patterns of change relating to his PS and SRL skills, as was reflected in the forum in which he acted in the role of a mentor.

Data and data analysis

In the course of the study, 96 protocols of the forums' work were obtained and analyzed. Of these, 72 protocols of the work of the forums, in which teachers acted as learners (12 groups with a permanent composition) and 24 forums, in which some of the teachers acted as mentors. This paper focuses on the analysis of the PSF protocols of three forums of John's group, where John and the other participants act as learners in three forums (with the facilitator of the PD program as a mentor) and one forum in which John acts as a mentor, while the other forum participants are in the role of learners. For responding the first RQ, we present PSF protocols analysis that reflects the development of all participating teachers' SRL and PS. For responding the second RQ, we focus the analysis of the PSF protocols on the activity of John.

We have applied directed content analysis (Hsieh & Shannon, 2005) to code forums in light of SRL and collaborative PS theories. For the research unit, the message (post) sent by the participant was selected. Most of them were text messages, but sometimes participants posted a photo of a drawing or part of a solution. This method of analysis allowed us to analyze the data qualitatively as well as

quantify it as described below. First, we distributed the forum to posts, where each post was assigned two codes – one for collaborative PS and one for SRL. For collaborative PS, data analysis was based on the taxonomy proposed by Clark et al. (2014). This study examines the success of the PSF in terms of the level of group synergy achieved in the forum. There was evidence of group synergy in cases where a group of related posts from several participants discussed ideas for solving a problem. We calculated the ratio between the number of posts included in the synergy chains and the total number of messages on this forum. On the SRL aspect, forum posts were codified in accordance with the definitions of SRL models by Pintrich (2000) and Zimmerman (2000). We determined the level of SRL in each of the forums, both as a whole and per individual components. The SRL attributes were defined as follows: a post was classified as motivational if it indicated the participant's attitude to his knowledge, capabilities, and teamwork in the forum. A post was classified as cognitive if it contains specific mathematical actions aimed at solving a problem, such as: in my opinion point B will move to B'. With regard to metacognitive attributes, it was determined that a post refers to planning if it concerns the general analysis of the problem, the choice of the solution strategy, the definition of the general and intermediate goals, such as: Shall we start rotation around the center of a circle? Monitoring attribution was assigned to a post if it evaluates progress towards a solution in terms of correctness and effectiveness in achieving a goal, such as: Moment, checking. So, after the rotation K moved to M, then... Finally, a post was classified as reflection if it includes a retrospective look at the process of solving a solution problem, such as: The problem is interesting in that its first part solves a standard with a section of means. After assigning a classification for each message, we calculated the ratio between the number of messages for each component and the total number of messages in a given forum. These values are presented in the findings as percentages.

Findings

We will present three forums out of six in which John participated as learner: at the beginning (PSF1), in the middle (PSF3) and at the end (PSF6) of the part of the study in which the teachers were in the role of learners. All problems proposed for discussion in the forums were carefully selected in accordance with the criteria specified in the theoretical base and were equal in complexity. As an example, we will give a problem that was proposed to the participants for discussion in the first forum: "Given a square ABCD. Point K is on segment BC, and point M is on segment DC. Line AM bisects the angle KAD. Prove that the length of the segment AK is equal to the sum of the lengths of the segments BK and DM". The following table summarizes the performance of the group of teachers that John was a member of throughout the study.

Responding to the first RQ request, Table 1 and Table 2 present the SRL attributes and group synergy scores (respectively) that were assigned to all posts made by the entire group of teachers in these forums. Data is presented in percentage of the total number of posts in the presented forum.

The data indicate that with long-term participation in the PSF, the weight of group synergy in the discussion increases significantly, in parallel with increase in the number of messages related to the collaborative PS. In the final forum, almost all posts are related to SRL: 48% of them are meta-cognitive, while in the initial forums only 28% of posts were meta-cognitive.

Table 1: Indicators of SRL attributes at the initial, middle and final stages of teacher participation in forums as learners (P = planning; M = monitoring; R = reflection; Other = non-SRL messages)

SRL components		PSF 1	PSF 3	PSF 6
Metacognition	P	5	13	17
	M	14	16	17
	R	9	3	14
gCognition		23	22	24
Motivation		19	22	24
Other		30	24	4

Table 2: Indicators of group synergy at the initial, middle and final stages of teacher participation in forums as learners

PS interaction	PSF 1	PSF 3	PSF 6
Group synergy	9	32	61
Others	91	68	39

Moving forward to John’s case, we might delve into these changes, as well as responding to the second RQ that aims to explore the SRT and collaborative PS skills of John’s who were reflected in the forum in which he took part in the role of a mentor. Figure 1 demonstrates the dynamics of changes in the SRL components and the participation in the group synergy of John as an individual teacher. This figure contains characteristics that describe the forums in which John was in the role of learner, as well as the one forum he was in the role of mentor. The data in the figure is presented as the percentage of John's posts that we attributed to a certain type when analyzing the data, out of the total number of John's posts in the presented forum. For example, 66% of John's posts in the first forum had been classified as “Cognition”. An additional column shows John's participation in the group collaboration (the percentage of his posts that make up the group synergy of all his posts).

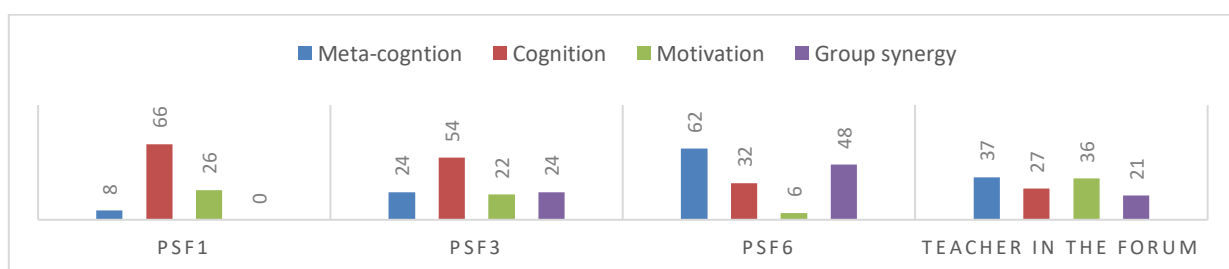


Figure 1: Jonn's activities in PSF as a learner and as a teacher

Figure 1 shows that, as in the group as a whole, an increase relating to the meta-cognitive component was seen in John's posts, in the forums where he participates as a learner. While low indication for metacognitive activity was revealed in the first forum, in the third forum over 60% of his posts were characterized as metacognitive. Another increase had been seen in the participation of John in group synergy. Particularly, in the third forum, group synergy was accounted for over 60% of group interactions and half of John's interactions. Below we describe the events that took place in each of the forums, focusing on John's activity.

Forum 1 is John's first attempt at PSF as a student. On this forum after a while (about 20 minutes) he published a complete solution to the problem. Soon, he removed the solution, saying it was wrong. John did not participate in the discussion. His motivational messages were about appeals to think, indications that the task is simple and multiple references to his successful solution. Forum 3 was John's third attempt to collaborate on the forum as a student. This time, John also did not participate in the discussion for a relatively significant period of time (about 15 minutes). He solved the problem again on his own. However, he did not publish the complete solution, but took part in the discussion, sharing his ideas. His reasoning was meta-cognitive in nature. For example, he shared with the group: "To prove that a polygon is a square, I started looking for segments that could be equal, and angles that should be 90. This gave me the idea to prove the equality of triangles in advance ...". In the last forum where John participated in the student role (Forum 6), he unexpectedly took the lead in the discussion. He reasoned and involved others in the discussion. The share of group synergy in this forum was 61%. And the average length of the synergetic chain (a number of interconnected and continuing each other messages related to the solution of the problem) was equal to 10.5 messages. This demonstrates the collective nature of the search for a solution. John was very much involved in the discussion. Often, a new round of discussion began with his proposal to think about other tasks of this kind or a proposal to return and analyze the data.

John's work as a teacher deserves special attention. Figure 1 shows that at this stage he has achieved a balanced proportion of SRL characteristics that are equally expressed. John participated in the discussion to stimulate group synergy in the students' work. He motivated them to jointly search for ways to solve the problem with phrases such as "Listen to each other. It will give you good thoughts." Most of John's advice was meta-cognitive. For example, "Let's talk about the essence of the problem and outline an action plan." The cognitive notes hinted at a way to solve the problem, not a direct solution. Many of John's posts as a teacher had prototypes in his student forums. These were either the lines of the group mentor or colleagues.

Discussion

The results of the study support the conclusions made in previous studies about the beneficial effect of self-experience as learners on the pedagogical activity of teachers, especially when it comes to the use of non-standard teaching methods (Hoover et al., 2016). Using the example of John and other teachers, we traced how their ability to listen and help the development of other people's ideas developed in the process of participation in the PSF, which is especially important in pedagogy aimed at developing independent thinking in students. We recorded a significant increase in the role of the meta-cognitive approach in solving problems by teachers, which was subsequently reflected in the role of John as a mentor of his colleagues. The participating teachers did not require the provision of a complete error-free solution by each learner separately, but facilitated a discussion aimed at

understanding the essence of the mathematical ideas inherent in the problems. At the same time, in the development of the idea of the double role of the teacher in light of the theory of SRL-SRT (e.g., Kramarski, 2012), it was found that the process of forming SRT in PSF environment occurs not only sequentially, but also in parallel with the development of SRL. It can be assumed that the explanation of the discovered phenomenon lies in the fact that the development of SRL skills in the process of participation in the work of forums contributes to the desire for a meta-cognitive assessment not only of the cognitive processes pertaining to the solution of the problem, but also a “top-down” view of the entire communicative and cognitive process, occurring in the forum. This conclusion is confirmed by numerous episodes of teachers' reflection on the processes taking place at the forum, both from the point of view of the ways of solving the problem, and from the point of view of the analysis of the interactions that took place. The discovered phenomenon makes it possible to use PSF, in which teachers solve mathematical problems, in a new context, as a model for exploring the mechanisms of development of communicative and mathematical aspects of teaching.

The present study has demonstrated the dynamics in the development of group synergy as participants gain experience of participating in PSF. A friendly, safe atmosphere has emerged in the forums, including mutual interest, willingness to listen and accept someone else's opinion, and not to be afraid to make mistakes in expressing one's opinion, which, according to Schindler & Bakker (2020), is necessary for the successful work of the group. We found that with an increase in the proportion of episodes of group synergy among interactions in the forum, groups progressed not only in terms of efficiency in solving problems, as Clarke and colleagues' research (2014) shows, but also in terms of self-regulation of their participants, in particular, their meta-cognitive approach to problem solving. It might be that the orientation of the participants towards self-regulation allowed them to notice and evaluate the episodes of successful joint work and purposefully strive to expand them, thus contributing to the emergence and strengthening of group synergy in the forums as a factor contributing to success.

In conclusion, this study contributes to the theory of the mutual influence of the collaborative solution of mathematical problems, in particular in the PSF environment, and the development of self-regulation skills. The fact that the participants of the forums are teachers allowed us to move to the next level of understanding of this issue and to trace the reflection of these processes on the pedagogical activities of teachers, in particular as mentors of PSF.

Acknowledgment

We would like to thank Prof. Boris Koichu from Weizmann Institute of Science, Israel, for his important role in this study.

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