# 11th Grade Students' Self-Regulated Learning in a Mathematics Problem-Based Learning (PBL) Classroom

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We proposed to study self-regulated learning (SRL) of 11th grade students in a PBL classroom ($n$ = 36). The data were collected in November 2016 using Students' Self-Regulation Strategy Inventory (Students' SRSI), Teachers' Self-Regulation Strategy Inventory (Teachers' SRSI), students' interviews forms, students' reflections, and the teachers' notes. Descriptive statistics (percentages, means, and standard deviations) and descriptive analysis were used to analyse the data. We found that in the PBL classroom, the students demonstrated self-regulated learning in three phases – the forethought phase, the performance phase, and the self-reflection phase – at high levels.

In the 21st century, students need to develop life skills along with content knowledge, thinking skills, and social and emotional competencies to be able to survive in this era of globalization (Trilling & Fadel, 2009). One of the important life skills is Self-Regulated Learning (SRL). SRL is the process by which individuals exercise autonomy and control cognition, affect, and behaviours to achieve a defined learning goal (Kaur, 2012; Zimmerman, 2000, 2002). In this study, we used the process of Zimmerman and Campillo's SRL (2003) that involved three phases as follows: (1) the forethought phase including task analysis (goal setting and strategic planning) and self-motivation beliefs (self-efficacy, outcome expectation, intrinsic interest/value, and goal orientation), (2) the performance phase including self-control (imagery, self-instruction, attention focusing, and task strategies) and self-observation (self-recording and self-experimentation), and (3) the self-reflection phase including self-judgement (self-evaluation and causal attribution) and self-reaction (self-satisfaction/affect and adaptive/defensive). The SRL has three phases. In the first phase, forethought refers to processes and beliefs of students before the students start to do their action or performance. In the second phase, performance refers to behavioural implementation and strategies for learning by students. In the third phase, self-reflection reflects students' evaluation of their achievement and their reactions to performance goals compared to the outcomes.

In the past, Thai students in formal education became accustomed to receiving knowledge from lectures by a teacher, which provided fewer SRL opportunities such as setting goals, communicating with their teachers and peers, getting feedback, and adapting their own knowledge during learning (Suanpang & Petocz, 2006; Tsai, 2010). These days, many Thai students are still accustomed to passive learning with less emphasis on SRL (Park & Nuntrakune, 2013). As still found in many countries, most Thai students showed a lack of SRL behaviours. For example, in the forethought phase, some students lacked goal-setting behaviours. They neither read nor planned on solving mathematics problems by themselves. In the performance phase, some students did not solve mathematics problems by themselves. Instead, they would rather wait to get assistance from their friends or to get answers from their teachers. In the self-reflection phase, some students were not concerned about self-evaluation. For instance, some students could not evaluate their assignments to check if their works were correct. In order to develop students' SRL, teachers must transform the students from passive learners to active learners (McDonough & Sullivan, 2008; Zimmerman, 2002).

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Several studies showed that SRL was fostered by Problem-Based Learning (PBL, Blumberg 2000; Sungur & Tekkaya, 2006). PBL is an active learning strategy that stimulates students to learn about a subject through real-world problems and promotes the development of critical thinking skills, problem-solving abilities, communication skills, and SRL (Duch, Groh, & Allen, 2001; Paris & Paris, 2001). Therefore, we were interested in studying 11th grade students' SRL in a mathematics PBL classroom. We adapted the PBL learning processes from Othman, Salleh, and Sulaiman's study (2013). They proposed five steps in the PBL processes: (1) an introduction to the problem, (2) self-directed learning, (3) group meeting, (4) presentation and discussion, and (5) exercises.

## Method

In this mixed-method research study, we aimed to study students' SRL in a mathematics classroom by implementing a PBL approach. The participants were 36 11th grade students (eight boys and 24 girls) from a high school in Chiang Mai, Thailand. The research instruments were:

1) Eight PBL lesson plans: One of the researchers taught the PBL lesson plans for four weeks in the second semester of the academic year 2016. Each lesson took 100 minutes.
2) Students' Self-Regulation Strategy Inventory (Students' SRSI), a 48-item self-report instrument with 5-point Likert scale adapted from Cleary's study (2006). Before using the Students' SRSI, we examined the reliability of students' SRSI by testing it in a parallel classroom ($n = 40$) (Cronbach's alpha co-efficient, $r = 0.92$).
3) Students' reflections
4) Students' interview forms adapted from Callan's study (2014)
5) The teachers' notes
6) The Teachers' Self-Regulation Strategy Inventory (Teachers' SRSI) adapted from Callan and Cleary (2012)

The participants took the Students' SRSI (Pre-Test) at the beginning of the lessons. In the classroom, data were collected by one of the researchers who taught the eight lesson plans. A mentor teacher observed the students in the classroom by using the Teachers' SRSI. In the meantime, other sources of data were students' reflections and the teacher's notes (Video recordings were used to provide backup data). At the end of all the lessons, Students' SRSI was used to verify the students' SRL (post-test) (Cronbach's alpha co-efficient, $r = 0.912$). Moreover, we selected nine students with mixed mathematical abilities (three high, three average, and three low) to interview in order to get in-depth information on SRL. The collected data were analyzed using both quantitative and qualitative methods. The data from Students' SRSI and Teachers' SRSI were analyzed by using descriptive statistics, including percentages, means, and standard deviations. The data from students' reflections, interview forms, and the teacher's notes were analyzed by descriptive analysis.

## Results

We employed a mixed-method design using multiple data sources, as described above to investigate 11th grade students' SRL in a PBL context. Our findings are presented according to Students' SRSI, Teachers' SRSI, students' interview forms, students' reflections, and teacher notes.

Regarding the students' SRSI, the mean scores of all three phases of SRL increased from the pre-test to post-test (see Table 1). The mean scores of the task analysis in the forethought phase showed the greatest improvement from pre-test to post-test. In contrast, the students' self-reaction in the self-reflection phase showed the lowest improvement. It can be noted that the mean scores of self-observation and self-reaction in the post-test were similar (Mean = 3.69).

Table 1
*Means and Standard Deviations of Scores on Students' SRSI (n = 36)*

| SRL Phase | Pre-test | | Post-test | |
|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. |
| Forethought | | | | |
| Task Analysis | 3.38 | 0.91 | 3.68 | 0.81 |
| Self-Motivation Beliefs | 3.59 | 0.90 | 3.70 | 0.84 |
| Performance | | | | |
| Self-Control | 3.31 | 0.90 | 3.56 | 0.82 |
| Self-Observation | 3.43 | 0.81 | 3.69 | 0.79 |
| Self-Refection | | | | |
| Self-Judgement | 3.45 | 0.92 | 3.54 | 0.78 |
| Self-Reaction | 3.60 | 1.01 | 3.69 | 0.90 |
| Overall | 3.46 | 0.91 | 3.64 | 0.83 |

Focusing on the analysis of teachers' SRSI based on observations in the PBL classroom, we found that the mean scores of all phases (i.e., the forethought phase, the performance phase, and the self-reflection phase) had an increasing tendency. In the forethought phase, the mean scores for task analysis were less than the mean scores for self-motivation beliefs (see Figure 1). In the performance phase, the mean scores for self-control were greater than the mean scores for self-observation in most of the PBL lessons (see Figure 2). In the self-reflection phase, the students' self-judgement mean scores were greater than the students' self-reaction in most of the PBL lessons (see Figure 3).

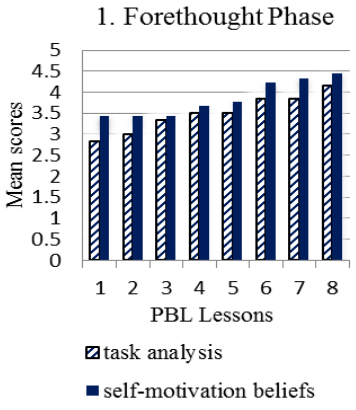



*Figure 1.* Mean scores of Students' SRL in Forethought Phase ($n$ = 36).

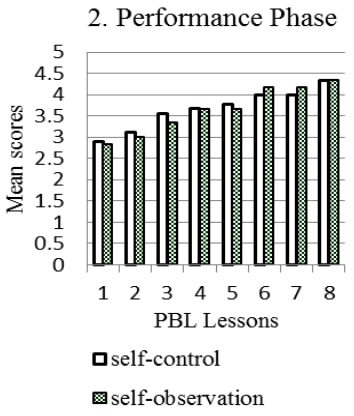



*Figure 2.* Mean scores of Students' SRL in Performance Phase ($n$ = 36).

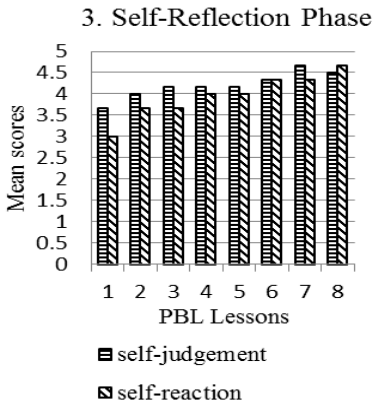



*Figure 3.* Mean scores of Students' SRL in Self-Reflection Phase ($n$ = 36).

In addition, the data from the interviews of the nine students from different mathematics achievement levels provided more details on the students' SRL in the forethought phase, the performance phase, and the self-reflection phase, which are presented in Tables 2, 3, and 4, respectively.

Table 2
*SRL in the Forethought Phase from Students' Interviews*

| Mathematics Achievement Level | Forethought Phase |
|---|---|
| High | 1. Task Analysis: The students set very clear goals to complete the assignments (Goal setting). They had their plans to select or create the best ways to solve the problems (Strategy planning).<br>2. Self-Motivation Beliefs: The students were very confident in their efficacy for solving the problem situation (Self-efficacy). They not only believed that their solutions were aligned with their goals (Outcome expectation), but also believed that mathematics was valuable to their daily lives (Intrinsic interest/value). |
| Average | 1. Task Analysis: The students set pretty clear goals to complete the assignments (Goal setting). They had plans to select or create the best ways to solve the problems (Strategy planning).<br>2. Self-Motivation Beliefs: The students were confident in their efficacy to solve the problem situations (Self-efficacy). They also believed that their solutions aligned with their goals (Outcome expectation). They believed that value of mathematics was only for doing the exams (Intrinsic interest/value). |
| Low | 1. Task Analysis: The students set vague goals to complete the assignments (Goal setting). They were uncertain about their plans for selecting or creating the best ways to solve the problem (Strategy planning).<br>2. Self-Motivation Beliefs: The students were uncertain about their efficacy to solve the problem situation (Self-efficacy). They were uncertain that their solutions were aligned with their goals (Outcome expectation). Moreover, they believed that the value of mathematics was only for doing the exams (Intrinsic interest/value). |

As seen in Table 2, focusing on the students' SRL in the forethought phase, we found that all of the students explained the behaviours and belief in their task analysis (goal setting and strategies planning) and their self-motivation belief (self-efficacy, outcome expectations, and intrinsic interest/value). The students with high mathematics achievement had very clear goal setting and self-efficacy, greater than that of the other students. In addition, the students with average and low mathematics achievement believed that the value of mathematics was only to benefit them in doing the exams.

Table 3
*SRL in the Performance Phase from Students' Interviews*

| Mathematics Achievement Levels | Performance Phase |
|---|---|
| High | 1. Self-control: The students preferred self-instruction such as thinking aloud and asking themselves questions. They preferred task strategies such as underlining important information and planning before solving problems. |
| | 2. Self-observation: The students preferred self-recording such as taking notes and checking their solutions. |
| Average | 1. Self-control: The students preferred imagery such as drawing pictures to do mathematics. They preferred task strategies such as rereading the problems and planning before solving problems. |
| | 2. Self-observation: The students preferred self-recording such as taking notes and checking their solution. They tried to use self-experimentation such as using different strategies in the same problem situations. |
| Low | 1. Self-control: The students preferred attention focusing such as rechecking their answers. They preferred task strategies such as rereading the problems. |
| | 2. Self-observation: The students preferred self-recording such as taking notes. However, they did not use taking notes to recheck their solutions. |

As presented in Table 3, focusing on SRL in the performance phase, we found that the students showed different preferences for self-control (self-instruction, imagery, attention focusing, and task strategies). In the self-observation sub-process (self-recording and self-experimentation), the students with high and low mathematics achievement preferred self-recording such as taking notes, but the students with low mathematics achievement did not recheck their solutions in their notes. The students with average mathematics achievement added self-experimentation for finding the best ways to solve the problem because they wanted to confirm their answers again.

Table 4
*SRL in the Self-Reflection Phase from Students' Interviews*

| Mathematics Achievement Levels | Self-Reflection Phase |
|---|---|
| High<br><br>Average | 1. Self-judgment: The students evaluated the strategies that they used in doing tasks by comparison with their goal (Self-evaluation). They could explain the causes of success or failure in an assignment (Causal attribution).<br>2. Self-reaction: The students were satisfied with the strategies and solution that they used (Self-satisfaction/affect). They wanted to improve by using new ones to obtain better results (Adaptive/defensive). |
| Low | 1. Self-judgment: The students evaluated the strategies that they used in doing tasks by considering their feelings (Self-evaluation).<br>2. Self-reaction: The students were not satisfied with the strategies and solution that they used (Self-satisfaction/affect). They wanted to improve the mistakes in mathematical process such as calculating mathematics (Adaptive/defensive). |

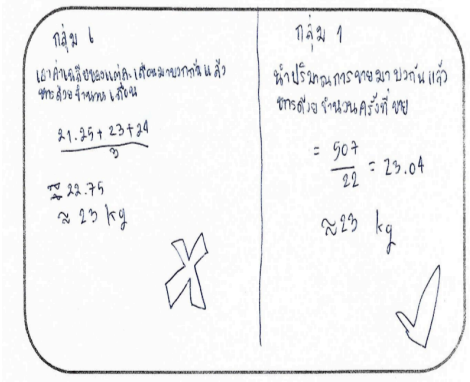
As presented in Table 4, focusing on the SRL in the self-reflection phase, we found that the students with high and average mathematics achievement had similar perspectives about self-judgment (self-evaluation and causal attribution) and self-reaction (self-satisfaction/affect and adaptive/defensive). In contrast, the students with low mathematics achievement used their feelings to evaluate tasks instead of using their goals. They could not give reasons about the causes of success or failure in an assignment. They had less satisfaction with their strategies and solutions than the students with high and average mathematics achievement.

Furthermore, the data analysis from students' reflection and teacher's notes showed the Students' SRL in the PBL classroom by focusing on the forethought, performance, and self-reflection phases. The Students' SRL are discussed next.

In the forethought phase, most students (80%) showed improvement in their task analysis (goal setting and strategic planning) and self-motivation beliefs (self-efficacy, outcome expectations, intrinsic interest/value, and goal orientation) in the 1st, 2nd, and 3rd steps of the PBL process: an introduction to the problem, self-directed learning, and group meeting. For example, in the 1st step of the PBL process, after the teacher introduced the problems, the students created goals of learning (goal setting). For example, "I want to learn and understand the tasks by myself so that I can use it in my daily life or use it to learn in higher education". The students believed that they must understand mathematical content in the problem situation (outcome expectation). In the 2nd and 3rd steps of the PBL process, the students planned to solve the problems by trying find the means required for the problem situation or trying to manage their time and group members' duties in solving the problem (strategies planning).

In the performance phase, most students (85%) showed improvement in their self-control (self-instruction, imagery, attention focusing, and task strategies) and self-observation (self-recording and self-experimentation) in the 2nd, 3rd, 4th, and 5th steps of the PBL process: self-directed learning, group meeting, presentation and discussion, and exercises. For example, in the 2nd and 5th steps of the PBL process, the students used many strategies to solve the problem. For example, they used imagery such as drawing pictures or using mind mapping or they underlined the important points and marked the questions to help them solve the problem situation (task strategies). They tried to find the best solution from their prior knowledge or their experience (self-experimentation). In the 4th step of the PBL, they tried to record the important data to make conclusions from their learning (self-recording).

In the self-reflection phase, most students (78%) showed improvement in their self-judgment (self-evaluation and causal attribution) and self-reaction (self-satisfaction/affect and adaptive/defensive) in the 2nd, 3rd, 4th, and 5th steps of the PBL process: self-directed learning, group meeting, presentation and discussion, and exercises. For example, in the 2nd and 5th steps of the PBL process, the students rechecked their answers with friend (self-evaluation). They evaluated their performance by level of satisfaction. They were rather satisfied of their solution. In the 4th steps of the PBL processes, they evaluated and adapted the solutions of problems presented by other students in order to identify their solution for the problem situations (see Figure 4).



Group 6
Sum mean of
Each month, and
divided the
summation with the
number of months

$$\frac{21.25 + 23 + 24}{3}$$

$$= 22.75$$

$$\approx 23\text{kg}$$

Group 1
Sum sale quantities,
and divided the
summation with
terms of sales

$$\frac{507}{22}$$

$$= 23.04$$

$$\approx 23\text{kg}$$

*Figure 4.* Example of self-evaluation the solutions of problems by presentations of other students. The left image shows a student's work, and the right shows its English translation.

## Conclusion

The findings of this study showed that 11th grade students in a PBL classroom demonstrated the SRL in all three phases: the forethought, performance, and self-reflection phases, based on the study of Zimmerman and Campillo (2003). By using Students' SRSI adapted from Cleary (2006) and Teachers' SRSI adapted from Callan and Cleary (2012), we found that the students' mean scores in all phases of SRL increased. The results of the study, from interviews with students, students' reflections, and teachers' notes showed that in the 2nd step of the PBL processes (self-directed learning), the forethought and performance phase were observable. In the 4th step of the PBL processes (presentation and discussion), the students showed obvious expressions SRL in the self-reflection phase.

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