# Using the Self-regulated Based Personalized Online Learning System for Learning Factorization in Mathematics

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**Abstract:** Developing a self-regulated based personalized online learning system (SPOLS) for learning factorization aimed to provide appropriate learning materials that allow students to learn factorization and control themselves to accomplish their target. The study aimed to investigate the impact of using SPOLS on students' learning achievement and their perception of online self-regulated ability. The participants consisted of a single group comprising seventy-two eighth-grade students. They were administered pre- and post-tests before and after completing a lesson on factorization. Additionally, they were required to rate their scores on an online self-regulated questionnaire before and after utilizing SPOLS. The results showed that incorporating SPOLS led to a statistically significant increase in the average students' achievement on the post-test for the numerical factorization compared to their performance on the pre-test. However, using SPOLS for learning polynomial factorization did not elicit a statistically significant change in achievement scores. Moreover, in part of the self-regulated ability, after using SPOLS participants' scoring on pre- and post-self-regulated questionnaires, Chi-square implies discovering the relationship between two categorical variables. The result showed that seventeen questionnaire items were statistically significant after using SPOLS.

**Keywords:** Personalized online learning system, self-regulated, factorization, ubiquitous learning, mathematics

## 1. Introduction

One strength of implementing technology in the classroom was assisting the oversight a general classroom hardly reaches. So, the idea of personalized learning usually appears in the context of online learning systems since it enables access to such a system anywhere, anytime. Personalization's intent spurred motivational and metacognitive states like positive affect and focused attention (Ingkavara et al., 2022; Panjaburee et al., 2022; Walkington & Bernacki, 2014, 2019). However, the personalized online learning system might not stand alone without a learning approach since the freedom to use of personalized online learning system can cause learning issues. Such as, students delay finishing the course and are lost in peer interaction. It reflects in the lack of ability to control themselves to accomplish the target, says self-regulated learning.

Self-regulated learning (SRL) is the self-process and self-beliefs that enable learners to transform their mental abilities into academic performance skills. With this, SRL is considered the proactive process that one uses to drive themselves to accomplish learning; for instance, goal setting, strategies selection, seeking help, or self-evaluation (Zimmerman, 2008). With all these SRL strategies, it turns a massive amount of work for students to carry and accomplish in the general classroom setting; that is why technology becomes an efficient assistant. So, this raises the challenges of well-combination self-regulated learning strategies into a personalized online learning system to help students achieve in the learning content.

Other points related, as from a decade review articles (2010-2020) of Lai and Hwang reported, there were just five studies from a hundred focused on using the SRL strategy in e-learning for mathematics (Lai & Hwang, 2021). It is well known that Mathematics is a subject that content mainly presents as numerical, symbolic, and variable. Therefore, most students would be difficult even to begin or give up on learning. With this, an understanding of those abstract notions and their concepts is proposed to decrease confused learning and also gain the ability to learn new knowledge related to the previous concept (Bruner & Kenney, 1965). Likewise, quadratic polynomial factorization is one categorized as fundamental in learning Algebra; still, few researchers relied on this content in personalized online learning systems with SRL strategies. Therefore, developing a self-regulated-based personalized online learning system (SPOLS) becomes challenging for this study by referring to an existing design of our previous study (Ingkavara et al., 2022). With two points looking for, does learning achievement differ when students receive the SPOLS for learning factorization in mathematics, and do students' perceptions of their online SRL differ before and after using the SPOLS for learning factorization in mathematics?

## 2. Development of Self-regulated Based Personalized Online Learning System

### *2.1 The Self-Regulated Based Personalized Online Learning System (SPOLS)*

SPOLS is developed from the principles of learning preference-based learning systems. It states that individuals could receive proper learning materials relevant to their preferences and provide each conceptual learning outcome (Ingkavara et al., 2022). In addition, SRL strategies are added to assist students in achieving their learning, and the using steps are described as follows:

- The system provides learning materials corresponding to personal learning styles.
- All are asked to set personal goals and sequence learning contents (Figure 1).
- Before involving learning activities, a pre-test needs to be done; the system diagnoses learning ability and provides learning status, which allows students to adjust goals along the learning process (Figure 2).
- Complete post-tests after finishing all contents; the system displays getting scores for each (Figure 3).
- Personal learning analysis summarizes the overall learning achievement, outcome comparison between pre-and post-test, success percent of learning achievement, and success percent of learning time given (Figure 4).
- After finishing all lessons, SPOLS allows retesting and relearning with other learning materials.

### *2.2 E-learning Materials in SPOLS for Learning Factorization in Mathematics*

The e-learning materials are typically concerned in two parts. One was about various learning materials, and the second was conceptual knowledge in factorization. Four learning materials were adopted regarding Felder-Silverman's Model to cover personal learning preferences to fit the online learning system as proposed in a previous study (Panjaburee & Srisawasdi, 2016). There relies on four characteristics likes active-visual, reflective-visual, active-verbal, and reflective-verbal.

For conceptual knowledge, this system provided two main contents (i.e., numerical and quadratic polynomial factorization). Using virtual algebra tiles is the core idea in developing all these learning materials (Fosnaugh & Mitchell, 2014; Garzón & Bautista, 2018). Students acquired factorization knowledge from the relation of rectangle area that displays as a product of two numerical or even specific two-terms (width and length).

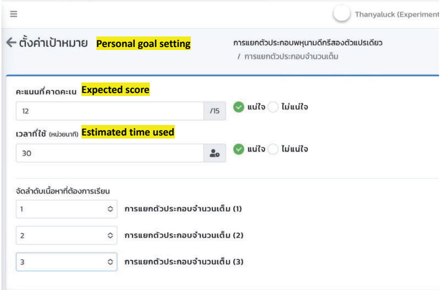

*Figure 1.* Personal goal setting.

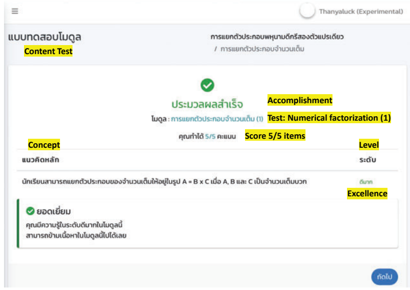

*Figure 2.* Accomplishment in content.

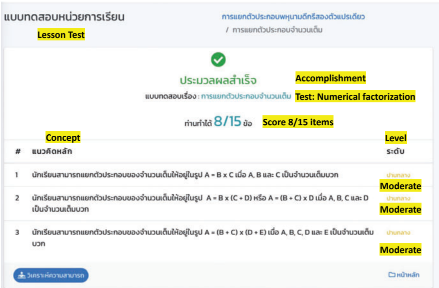

*Figure 3.* Accomplishment in the lesson.

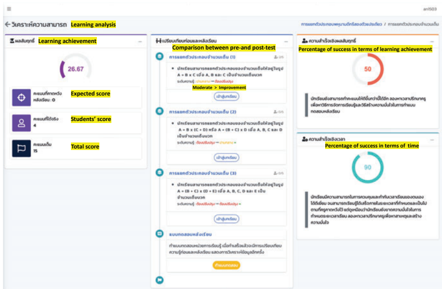

*Figure 4.* Learning analysis.

## 3. Research Methodology

The non-experiment with a quantitative approach was applied in this study to investigate students' achievements before and after the incorporation of SPOLS; at the same time, students' perception of online SRL ability before and after was also found out. In this study, 72 eighth-grade students used SPOLS in the second semester 2022. Therefore, one could study through SPOLS within a month according to one's strategy to accomplish all lessons. Firstly, students were asked to take a pre-online self-regulated learning questionnaire (OSLQ) and a pre-learning achievement test (numerical factorization) followed by activities. Then take the post-learning achievement test (numerical factorization) after finishing all lessons. Secondly, the pre-learning achievement test (polynomial factorization) was asked to take before going with polynomial factorization activities. And finished by taking the post-learning achievement test (polynomial factorization) and scoring on the post-OSLQ.

The four multiple-choice scores awarded for each correct answer were used to answer the first research question. There are fifteen test items for numerical factorization content, while twenty-five items for polynomial factorization, say five questions per sub-lessons. In addition, to answering the second research question, The OSLQ was conducted in this study (Barnard et al., 2009). There were six evaluation subscales, twenty-four items with a five-point Likert scale. The internal consistency of the score by subscale values for Cronbach alpha ranged from 0.67 to 0.90, implying a reliable questionnaire. This study conducted back translation to ensure the content and communication validity of the questionnaire.

## 4. Results

### *4.1 Learning Achievement*

After all, data was collected, descriptive analysis was computed to describe pre-and post-test data sets by generating summaries about data samples. The findings represent two cohorts related to the content study. For the numerical factorization lesson, the results pointed out the increase of mean score in achievement after students use SPOLS for learning ($M_{pre}$= 10.26, $M_{post}$= 11.03), and the achievement score showed more relatively consistent in the post-test ($S.D._{pre}$= 4.624, $S.D._{post}$= 4.097). While for the polynomial factorization lesson, the mean score of the post-test a little bit increased ($M_{pre}$= 14.90, $M_{post}$= 15.32); in contrast, the relatively consistent show a decreasing in the post-test ($S.D._{pre}$ = 8.000, $S.D._{post}$= 8.299).

The Wilcoxon signed-rank test was conducted to see a comparison. In the case of numerical factorization, 33 students had a higher score on the post-test than on the pre-test. However, 25 students had no change in their scores, while 14 had a higher score in the pre-test. A Wilcoxon signed-rank test showed that using SPOLS for learning numerical factorization elicited a statistically significant change in learning achievement ($Z = 3.293$, $p < 0.001$). For the polynomial factorization, nearby results indicated that ten students had no change in score. An exciting was that 32 students got higher scores on the post-test while 30 students were on the pre-test. These results are a significant concern since it is about 41% that students perform not as well. A Wilcoxon signed-rank test showed that using SPOLS for learning factorization in polynomials did not elicit a statistically significant change in learning achievement ($Z = 0.820$, $p = 0.412$).

### *4.2 Perception of Online Self-regulated Learning Ability*

The students were asked to rate their perception toward OSLQ, pre- and post-using SPOLS for learning factorization. Chi-squares were conducted to discover the relationship between pre- and post-perceptions. Findings revealed that students' perception was statistically associated with 17 questionnaire items covering five SRL strategies (out of six): goal setting (GS), task strategies (TS), time management (TM), help-seeking (HS), and self-evaluation (SE). The GS strategy resulted in three sub-items that showed statistically significant with $\chi(4) = 9.917$, $p = 0.042$, $\chi(4) = 22.445$, $p < 0.001$, and $\chi(4) = 11.062$, $p = 0.026$, respectively. Phi value tests of these three sub-items showed the strength of association between the variables at a moderate level (0.262 – 0.395). Mean students perceived goal setting and maintaining a high academic standard despite an online course, and students agreed more to not compromise on the quality of assignments because this was an online study, respectively. Moreover, the increasing trend of SRL perception after using SPOLS for these three sub-items, with students' ratings "strongly agreeing" almost doubled. In contrast, the environment structuring (ES) strategy was the only one that was not statistically significant. Most of the Phi values showed the strength of association between the variables at a weak level. While the surprise was on the TS strategy, students' perception indicated that after using SPOLS, their perceptions were highest from all sub-items. Four of them showed a statistically significant difference $\chi(4) = 11.371$, $p = 0.023$, $\chi(4) = 14.283$, $p = 0.006$, $\chi(4) = 16.759$, $p = 0.002$, $\chi(4) = 20.350$, $p < 0.001$, respectively. The most rated frequency in "strongly agree" is that they agreed to practice solving problems on SPOLS to become more proficient.

For the TM strategy, three sub-items showed statistically significant with $\chi(4) = 26.174$, $p < 0.001$, $\chi(4) = 10.151$, $p = 0.038$, $\chi(4) = 11.585$, $p = 0.021$. However, there was one sub-item that showed a relatively strong level of association, which most students rated changing from "neutral" to "agree" and "strongly agree" levels after using SPOLS. Mean that students set more time for learning because they know this is a time-consuming activity but might not be strict, like the same time on the same day. In a while, HS strategy, three sub-items showed statistically significant with $\chi(4) = 16.991$, $p = 0.002$, $\chi(4) = 26.475$, $p < 0.001$, and $\chi(4) = 17.427$, $p = 0.002$, respectively. Thirty-three students rated the "strongly agree" level after using SPOLS. It indicated that they shared problems with their classmates when using SPOLS, so they knew what they were struggling with and how to solve it. Lastly, SE strategy, all sub-items revealed statistically significant, $\chi(4) = 29.478$, $p < 0.001$, $\chi(4) = 14.490$, $p = 0.006$, $\chi(4) = 10.900$, $p = 0.028$ and $\chi(4) = 12.559$, $p = 0.014$, respectively. Considering the rating frequency, the highest frequency, 31, was about students agreeing to summarize online studies to check their understanding of what they learned.

## 5. Discussion and Conclusion

The pre-and post-factorization test's descriptive analysis was separated into two contents, numerical and polynomial factorization. In the numerical factorization, the mean of the post-test is higher than the pre-test ($M_{post}$ = 11.03, $M_{pre}$ = 10.26), the same as the mean of the polynomial factorization ($M_{post}$ = 15.32, $M_{pre}$ = 14.90). Consider the mean difference of each content. Numerical factorization content showed 33 students (45.83%) who improved their factorization ability after using SPOLS. In comparison, 14 students (19.44%) got less than before the study, and 25 students (34.72%) still the same these results show statistically significant at $p < 0.001$. In contradiction, the polynomial factorization content was not statistically significant. However, considering the mean difference probably found the truth that most of the students can improve their ability in factoring polynomials by using SPOLS, 32 students (44.44%), but with the nearest of students who showed a decreasing score, 30 students (41.67%) might unclearly to make a strong confirmation that the use of SPOLS can improve the ability in factoring a polynomial. Overall, learning achievement slightly complies with previous studies that using a personalized online learning system can promote learning achievement (Chen et al., 2020; Chu et al., 2021; Panjaburee et al., 2022). However, one point mentioned, referring to the result of the achievement score of polynomial factorization content, is that it would be better further to seek the leading cause of this issue. Further in-depth study, including individual interviews, might concern task strategies and this group's learning path.

Students scored their perception on OSLQ among using SPOLS for learning. Overall, the result pointed to 17 statistically significant items after using SPOLS. However, one SRL strategy was not substantial, ES. Considering the frequency of score rating, it found that most students rated "strongly agree" on the ability to choose a comfortable place for study, but this frequency still decreased from before. So, finding a learning space that lets them occupy their full potential is pretty hard. Truly that an appropriate learning tool for accessing SPOLS is a computer or laptop; this might generate a messy thing for students since it might state in the public area of a house. So, developing a system or activity that fits portable devices, such as smartphones, the tablet can lead to further study. Next, three sub-items of setting goals in learning showed significance, mean to whether short or long-term, they still set goals and not compromising the quality of assignments just because this is an online study. Since SPOLS's feature allows students to set a goal at the beginning as long as reset to meet their comfortable, it slightly tailors the target, which motivates them to achieve at the end, which corresponds to the point that even this is the online course they will not reduce the quality in learning. This point corresponds to previous studies that technology could support students in setting their learning goals and instantly monitoring their learning process (Lai & Hwang, 2021). For TS strategy's results showed significance in perception generally state conduct notetaking, talking aloud when doing an activity, preparing discussion-question, and practicing more in the system. It is; therefore, SPOLS provides personalized learning material which fits their learning style, which this point might support learning strategies individually. Likewise, other previous studies that provide individual learning material and activity adjusting based on their preference might help students achieve. (Chu et al., 2021; Walkington & Bernacki, 2019). TM strategy, which focuses on setting extra time to learn, showed statistically significant in that SPOLS was not required every fixed time to study each content but was concerned about the ability to control and achieve what was set before. And for the HS strategy relied on how they sought help and exchanged ideas with friends and teachers. This stage reflected that students know themselves in the problem; one feature that helps them in SPOLS is each learning content status, turning awareness to improve until achieved, which is like SE strategy, which mentions the ability to evaluate themselves. It generally describes the perception of SRL toward using SPOLS for learning, as what is known as SRL is a cyclical process in which student plans, monitors their performance, and then reflects on the outcome (Zimmerman, 1986). The cycle can repeat as one uses until achieved, so it does not fit all as linear. That is why it should be tailored for personnel with specific learning paths. Also, technology becomes the answer to this point, enhancing cognitive and expected learning ability.

In summary, using SPOLS for learning factorization in mathematics can enhance learning achievement in numerical content. In contrast, the perception in SRL showed significance in seventeen of the sub-item. Furthermore, two strategies (i.e., task strategies and self-evaluation) showed statistically significant in all sub-item, indicating that using SPOLS can enhance self-regulated ability, especially in task strategies and self-evaluation.

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## References

Barnard, L., Lan, W. Y., To, Y. M., Paton, V. O., & Lai, S. L. (2009). Measuring self-regulation in online and blended learning environments. *Internet and Higher Education*, *12*(1), 1–6. https://doi.org/10.1016/j.iheduc.2008.10.005

Bruner, J. S., & Kenney, H. J. (1965). Representation and Mathematics Learning. *Monographs of the Society for Research in Child Development*, *30*(1), 50. https://doi.org/10.2307/1165708

Chen, I. H., Gamble, J. H., Lee, Z. H., & Fu, Q. L. (2020). Formative assessment with interactive whiteboards: A one-year longitudinal study of primary students' mathematical performance. *Computers & Education*, *150*, 103833. https://doi.org/10.1016/j.compedu.2020.103833

Chu, H. C., Chen, J. M., Kuo, F. R., & Yang, S.-M. (2021). Development of an Adaptive Game-Based Diagnostic and Remedial Learning System Based on the Concept-Effect Model for Improving Learning Achievements in Mathematics. *Technology & Society*, *24*(4), 36–53. https://doi.org/10.30191/ETS.202110_24(4).0003

Fosnaugh, L., & Mitchell, P. (2014). Teaching Tricks Can Be Tricky. *The Illinois Mathematics Teacher, 62*(1)*,* 10–14. Accessed: May. 7, 2023 [Online]. Available at: http://journal.ictm.org/index.php/imt/article/download/71/83

Garzón, J., & Bautista, J. (2018). Virtual Algebra Tiles: A pedagogical tool to teach and learn algebra through geometry. *Journal of Computer Assisted Learning*, *34*(6), 876–883. https://doi.org/10.1111/jcal.12296

Ingkavara, T., Panjaburee, P., Srisawasdi, N., & Sajjapanroj, S. (2022). The use of a personalized learning approach to implementing self-regulated online learning. *Computers and Education: Artificial Intelligence*, *3*, 100086. https://doi.org/10.1016/j.caeai.2022.100086

Lai, C. L., & Hwang, G. J. (2021). Strategies for enhancing self-regulation in e-learning: a review of selected journal publications from 2010 to 2020. *Interactive Learning Environments*, 1–23. https://doi.org/10.1080/10494820.2021.1943455

Panjaburee, P., Komalawardhana, N., & Ingkavara, T. (2022). Acceptance of personalized e-learning systems: a case study of concept-effect relationship approach on science, technology, and mathematics courses. *Journal of Computers in Education*, *9*(4), 681–705. https://doi.org/10.1007/s40692-021-00216-6

Panjaburee, P., & Srisawasdi, N. (2016). An integrated learning styles and scientific investigation-based personalized web approach: a result on conceptual learning achievements and perceptions of high school students. *Journal of Computers in Education*, *3*(3), 253–272. https://doi.org/10.1007/s40692-016-0066-1

Walkington, C., & Bernacki, M. L. (2014). *Motivating Students by "Personalizing" Learning around Individual Interests: A Consideration of Theory, Design, and Implementation Issues* (pp. 139–176). https://doi.org/10.1108/S0749-742320140000018004

Walkington, C., & Bernacki, M. L. (2019). Personalizing Algebra to Students' Individual Interests in an Intelligent Tutoring System: Moderators of Impact. *International Journal of Artificial Intelligence in Education*, *29*(1), 58–88. https://doi.org/10.1007/s40593-018-0168-1

Zimmerman, B. J. (1986). Becoming a self-regulated learner: Which are the key subprocesses? *Contemporary Educational Psychology*, *11*(4), 307–313. https://doi.org/10.1016/0361-476X(86)90027-5

Zimmerman, B. J. (2008). Investigating Self-Regulation and Motivation: Historical Background, Methodological Developments, and Future Prospects. *American Educational Research Journal*, *45*(1), 166–183. https://doi.org/10.3102/0002831207312909