# Design and Assessment of a Personalized Online Mathematics Learning System with Self-Regulated Learning Features: An Educational Design Research

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***Abstract*—A personalized online learning system incorporating a self-regulated learning approach was developed to deliver the factorization in quadratic polynomials topic on mathematics learning. This system created four learning materials for learning a certain topic in mathematics, corresponding to the students' characteristics. This study followed the education design research approach to develop a self-regulated-based personalized online learning system and evaluate the system from a technology acceptance perspective. The Pearson correlation was computed and revealed the best fit of the collected data for further stepwise multiple regression analysis through students' acceptance of learning mathematics before and after using the developed system. Furthermore, the Chi-square test was performed to determine the acceptance change and frequency rated by items to ensure an in-depth understanding of how acceptance changed before and after. Although the findings revealed that students' perceived ease of use was primarily a predictor of their attitude about the system, they showed an increment in perceived usefulness after participating in the developed system. The students' perceptions of ease and attitude toward the self-regulated-based personalized online learning system for mathematics learning should be mainly considered in further development, including the different learning approaches for supporting mathematics learning.**

***Keywords*—personalized online learning system, self-regulated, mathematics education, perceptions**

## I. Introduction

The emergence of technology becomes an alternative learning environment nowadays since it has the capacity to deliver some social behaviors that might be difficult to generate in general classroom environments, such as responding to each person on time, learning material suitable for personal style, or even re-explaining the same contents for those who still raise curiosity in one class. The Personalized Online Learning System (POLS) is one upcoming trend implemented in mathematics classes [1–3]. Even though findings slightly delivered significant improvements on those testing parameters, questions are still raised with the point that implemented existing interventions are precisely suitable for online mathematics lessons, which are regarded as abstract content. At the same time, the flexibility in using POLS is much more appropriate to provide learning strategies, which might support the ability to control oneself to achieve lesson learning. To cope with this issue, the development of a Self-regulated Personalized Online Learning System (SPOLS) for learning mathematics in which learning materials have been designed to support ways of visualizing algebraic concepts. With this, how students view SPOLS regarding mathematics learning sources in a personalized online learning system and how the design process could be when integrating mathematics with a personalized online learning system is still questioned. Moreover, examining the impacts of the technology acceptance model has been less investigated in technology-enhanced mathematics learning. That is to say, understanding students' perceptions toward the personalized online learning system is an issue when developing and evaluating personalized online learning usage for further improvement in actual use. Scholars mentioned that understanding predictors influencing the usage of personalized online learning systems would help design effective learning environments for students [4]. Therefore, Educational Design Research (EDR) became a framework for emphasizing designing and assessing predictors influencing usage of the personalized online mathematics learning system with self-regulated learning features with the following research questions:

1) How did SPLOS impact students' perceptions compared to their previous online learning experience?
2) What predictors influence the behavioral intention to use SPOLS for learning factorization in mathematics?

## II. Literature Review

### A. Personalized Online System and Mathematics Learning

The general characteristics of POLS serve to personalize learning by optimizing learning objectives, instructional approaches, and contents to the individual's pace of learning and needs [5]. So, the development of POLS attempts to deliver as much as possible to support each person, and its utilities have been investigated in several aspects, including cognitive and affective performance [1–3, 6]. The fact is that mathematics content in school is somewhat of an abstract concept. The difficulty and unaccountability of daily life can estrange most students. However, they are still important regardless of their level or career path [2]. Algebra is the concept in which students cross from the numerical world to variable aspects, which is fundamental to the other higher levels in mathematics. Several researchers tried to develop a solution that could help students personally understand this abstract concept. So, technology-based learning materials were always referred to because of their visualization capability. Previous scholars described relations between technology and mathematics as visually supportive in several

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expressions, including exploring, discovering, and modeling complex problems [7]. Likewise, in quadratic polynomials, to factorize, students generally find two numbers such that their product is equal to the last term and the sum equals the middle time of a given quadratic polynomial. The problem is that finding one to remember might not contribute to conceptual understanding, and one might also have trouble recalling this information in the long term. Algebra tiles, a geometric figure, have been introduced as a supportive tool in physical and virtual forms [8, 9]. The tiles generate a conceptual understanding by allowing students to manipulate, explore patterns, and develop the state of integers and algebra using geometric figures [9]. However, manipulating the algebra tiles to gain polynomial factorization understanding is fascinating but still does not cover the characteristics of POLS, which primarily target support personalization within the different personal learning styles. Therefore, extending various learning materials that support personalized learning in the online system regarding algebra tile concepts is considered for the content part.

### *B. Self-Regulated Learning and Online Learning System*

The flexible learning materials attribute also leads to unresponsible learning, so integrating some learning strategies is much more critical [10]. Self-Regulated Learning (SRL) strategies are a proactive process to achieve a learning goal. This process alters mental and behavioral performance, such as setting learning goals, picking proper learning strategies, asking for help when getting obstructed, and periodically evaluating themselves. In this regard, the personalized learning algorithms were applied to self-regulated online learning implementation [11]. There are three phases accommodated in applications regarding SRL: forethought, performance, and self-reflection [12–14]. As mentioned, there are several strategies to execute to become a self-regulated person, which is slightly tricky to cover in a general classroom, so scholars viewed technology-based learning as an alternative since its capacity can provide these mentioned strategies in one system and has been proven to have a significant impact on learners' SRL abilities [10, 15] Even though the idea of integrating SRL strategies with POLS has been advertised for a decade, it has still not been implemented in mathematics content [10]. Therefore, this is the trigger for developing a self-regulated personalized online learning system for learning factorization in mathematics.

### *C. Educational Design Research Approach*

Educational Design Research (EDR) is another type of research that contributes theory and develops and implements synthesized solutions to education challenges. One remarkable aspect of EDR is that, along the research path, the inquiry process is required chiefly to approach any actual learning settings, put forward solutions, or even yield new knowledge to get through educational challenges in practice while remaining theoretically supported and able to inform the work of others [16]. So, five outstanding characteristics indicate EDR: theoretically oriented, interventionist, collaborative, responsively grounded, and iterative [17]. Since dropped problems in an authentic learning setting are rarely on a linear solving precise solutions might cause those complexes. Previous scholars separately studied a particular goal's step, which belongs to research methodology. For example, Vesper's study [18] sought problems through a literature review and observation in an actual setting. Then, they developed the e-learning program's prototype and tested its effectiveness. After that, any obstacles or suggestions took them back to create and finalize a proposal for that learning intervention, including its approach and instruction use, which were effectively used in that content and further adapted to other fields. Likewise, the implementation of EDR as the framework was evaluated through multiple data sources, such as the design features of online learning resources in one university, and modified in implementation at a second different university within the same educational problem [19]. All the above points to the need for a multifaceted endeavor to systematically examine theoretical and practical aspects. So, in 2014, McKenney and Reeves proposed a generic model for conducting EDR, as shown in Fig. 1.

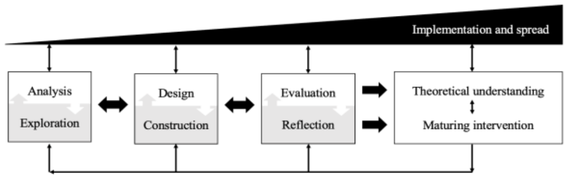


Fig. 1. A generic model for conducting educational design research adapted from McKenney and Reeves [16].

Three main phases, representing the scientific and practical, were mentioned iteratively and flexibly through the arrow line, besides showing the scope of increasing over time in implementation and spreading in practice. Analysis-Exploration phase proposes understanding problems, either literary or realistic. At the same time, Design-Construction is a part of problem-analyzed results that contribute to theoretical understanding or designing interventions. The Evaluation-Reflection phase is simply investigating how previous designs worked. After findings from empirical testing of the intervention, the proposal of an appropriate learning approach and intervention is provided as a reference for further study.

## III. Conceptual Research Framework

To come up with the findings of the above mentioned questions, the outline of three phases was mapped into this study and presented in Fig. 2. Firstly, the stage of Analysis-Exploration; this study refers to the previous review articles discussed earlier, which again showed few studies focused on implementing SRL strategies in technology-based learning environments for mathematics instruction [8]. In the same way, our previous study [11] implemented SRL strategies with a personalized online learning system to deliver physics content, which initiated an outperformed in students' achievement. Its use of systems extended a challenge to other knowledge content, such as mathematics. Thus, the system interface and content knowledge further described the second phase, Design-Construction. Lastly, the Technology Acceptance Model (TAM) sought Evaluation-Reflection phase to investigate the students' perceptions of using SPOLS in learning quadratic polynomial factorization. Any findings were analyzed, and the designed model suitable for further development for learning mathematics through SPOLS was proposed.

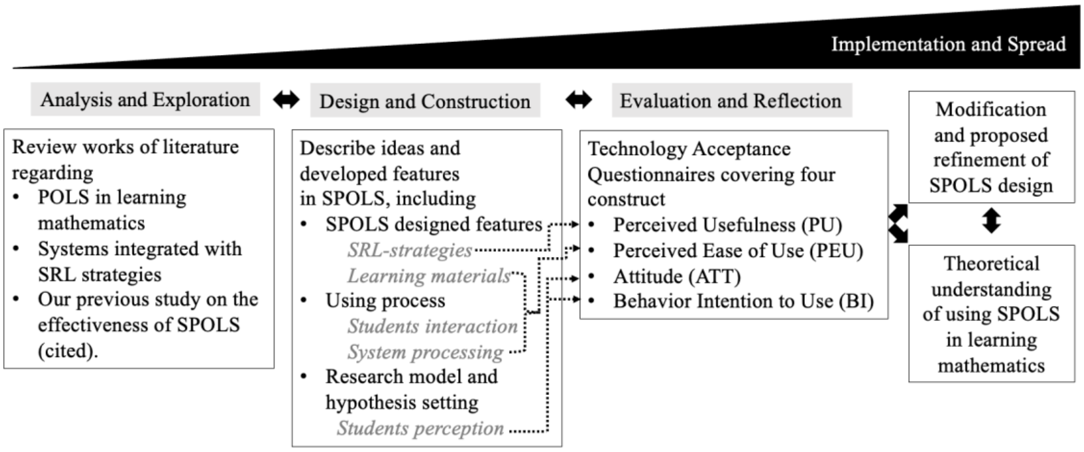


Fig. 2. Conceptual research framework based on an educational design research approach.

## IV. Design and Development

### A. *The Self-Regulated Personalized Online Learning System (SPOLS)*

SPOLS, the developing system, originated from previous scholars [11–23]. These previous studies relied on a concept-effect-oriented and preference-based learning system that aims at personalized instructional material, respecting preferences such as learning status, achievement, and the time used. Since SRL strategy interfaces were added to promote forethought, performance, and self-reflection phase as follows:

- The forethought phase interface allows students to identify the learning style that provides suitable learning materials. Classifying learning style is adapted from Felder and Silverman's questionnaire [24] with two dominant traits (i.e., active-reflective and visual-verbal) groupings aligned with previous studies [22]. The questionnaire consists of fourteen forced-choice questions that analyze learning styles from students' answers and then continuously provide proper learning materials in the learning activity. Moreover, goal-setting features, including expected learning score, time used, and lesson sequencing, were supplied before starting the learning cycle (Fig. 3).
- In the performance phase, system interfaces analyze learning status to inform students how much they knew before and show the progression after involving systems' activities. During the learning process, students can re-study as often as they like (Fig. 4).
- The self-reflection phase is the transition to the forethought phase, since the system allows users to pre-evaluate learning scores and ask again after learning activities and post-test to affirm self-evaluation (Figs. 5 and 6). Together with the system, they diagnose overall learning proficiency according to personal setting parameters. Users received feedback and suggestions for improving further learning achievement. With this, even if the user finishes learning activities in such a lesson, they still have a chance to re-study, re-test, and re-set strategies like trying other non-recommended learning materials before starting with the new tasks.

All algorithms of these phases include providing personalized learning materials regarding the learning style, checking and analyzing the learning status for each concept, diagnosing personal time achievement and learning proficiency, and providing recommendations in our previous study [11].

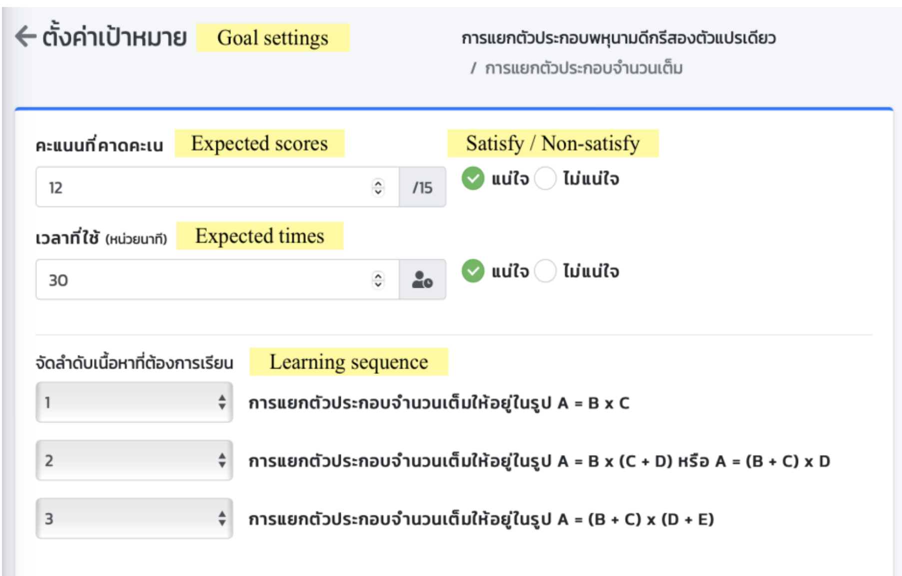


Fig. 3. The screenshot of integrating forethought features.

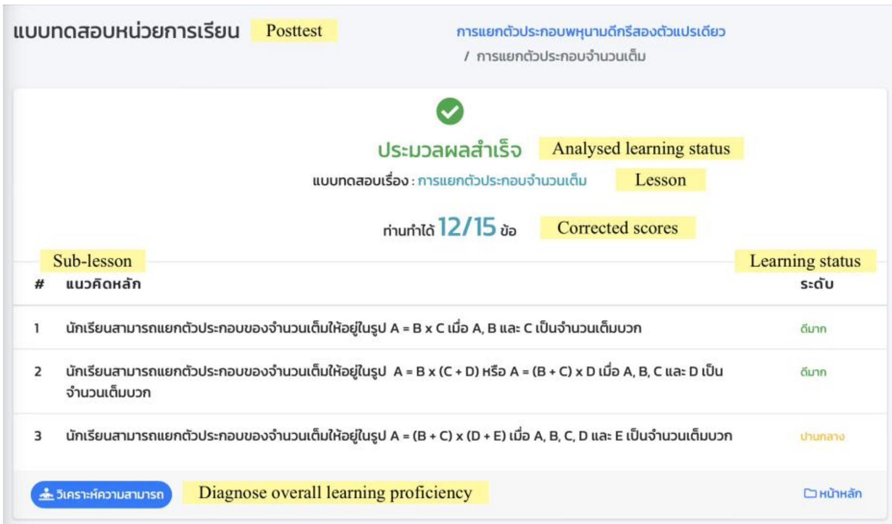


Fig. 4. The screenshot of integrating performance features in the system.


Fig. 5. The screenshot of integrating self-reflection features in the system.

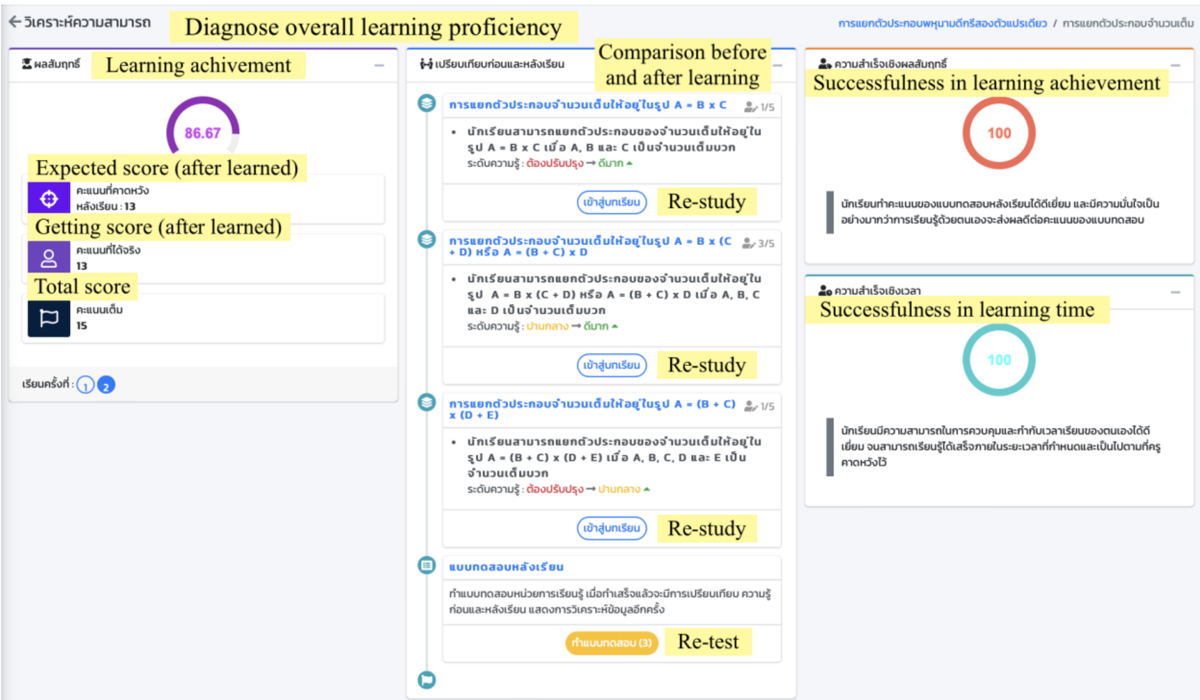


Fig. 6. The screenshot shows the overall summary of the learning through SPOLS.

In addition, the system provides each learning log as a report that allows the controller to observe users' learning paths. In the SPOLS environments, the user's view is used with the first login to the system and responding to the learning style test. The test is used to identify the proper layout of learning material for individual students. Before participating in learning tasks, the student was asked to complete the goal setting (Fig. 3) to propose achieving personal learning goals. When participating in a lesson, the system provides the pretest of each sub-lesson before walking through individual learning materials. In this part, the students can spend time learning based on personal needs, followed by taking a post-test. At the end of the post-test, the system asked them to confirm their confidence (Fig. 5), evaluate their learning ability in each sub-lesson (Fig. 4), and finalize with individual reports (Fig. 6), which showed how much they can manage themselves to finish this lesson learn. In addition, when the students have passed the learning tasks, the system allows them to select whether to re-learn with the same learning materials or other materials. Along the same lines, repeating testing to practice or gain more scores is possible. With these elements, using SPOLS for learning factorization in mathematics can assist in personalized learning, which the students can learn anytime based on individual preferences and progress.

### *B. Learning Materials for Learning Factorization in Mathematics*

Regarding the aims of promoting personalization amongst online learning systems, this study developed four types of learning materials regarding the learning style of Felder and Silverman's dimension. In this developed SPOLS, two of Felder and Silverman's index learning styles, active-reflective and visual-verbal, were selected to cross over as fitting in the online learning environment. With this, different learning materials are presented in SPOLS, such as digital games, diagram-based content, and VDO lecture-based content, to meet the needs of each person. The digital game represents the active style, while the diagram-based content illustrates the visual style learning material. The VDO lecture-based content typifies the verbal type, and blank space is regarded as the reflective style of writing down or reflecting based on what has been learned, all presented in Table 1.

Table 1. Learning materials corresponding to learning style in SPOLS

| Learning style | Learning materials |
|---|---|
| Active-Visual | Digital game with diagram-based content |
| Active-Verbal | Digital game with VDO lecture-based content |
| Reflective-Visual | Diagram-based content with VDO lecture-based content and online-taking notes |
| Reflective-Verbal | VDO lecture-based content and online notes |

As mentioned in the introduction, this study aims to deliver visualized learning algebraic materials through the SPOLS, which selects using algebra tiles as a prototype. All learning materials will provide information on factorizing numerals and polynomials with the algebra tiles. In contrast, each content provided is discussed in the next subtitle. The Algebra tiles are generally known as rectangles representing variables or constants. To form a quadratic polynomial, those represented tiles can be arranged into a new rectangle shape; with this, the area of the rectangle is equal to a given polynomials, while the relation between width and length sides are factors. Thus, students can observe how the area relates to factorization, including numerals and polynomials.

The digital game is identified as the materials for students with an active style. It was designed for individuals to play with a puzzle game style. The simple rule is to assemble those provided puzzles, which are algebra tiles, to form the game's assigned, that is, polynomials. At the beginning of the game, the introduction video will explain the difference in each tile's colors and sizes. The rules of tile arrangement (Fig. 7) are 1) the adjacent side of the tiles must be equivalent; 2) all need to form in a rectangle shape; and 3) the areas of the rectangle must be equal to given polynomials. For the given numerals or polynomials, the game also provides the factor below the width and length of the shape that students can observe when they assemble those tiles. Each playing round has limited times; the score will be gained when one makes it correct, while the score varies according to the complexity of a given polynomial. Students have a chance to replay as much as they want. The rules and agreement are the same as all sub-lesson and learning matters.

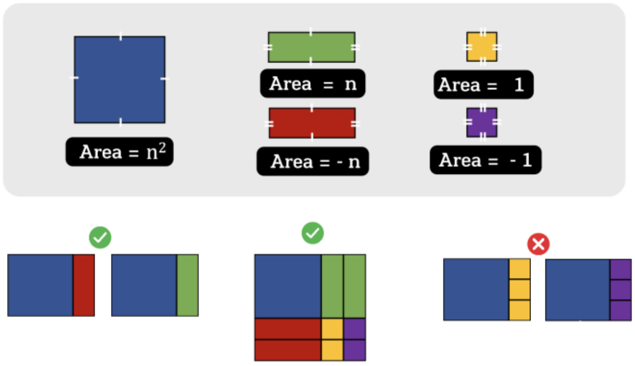


Fig. 7. The rules of tile arrangement.

Likewise, VDO lecture-based content is the teaching videos that take about 7–10 min. The teacher uses the algebra tiles to explain how numerical and quadratic polynomials are factored. In addition, a few examples were mentioned during teaching time to let students think about it. This material is suitable for students who love to listen rather than do. Similarly to diagram-based content, the factorization content was presented as an infographic that easily caught up within 1–2 pages; moreover, a few examples were included. For the online taking notes, specially designed for students who love notetaking when learning this material, the system provides a blank block that can be used to type alphabets and mathematics symbols. Nevertheless, the system automatically provides the learning materials based on students' learning styles resulted from the tests. So, in the first round, the students will learn through two materials that match their personal style test. At the same time, after they finish the lesson, the system allows them to participate in other learning materials if needed.

### *C. Quadratic Polynomial Factorization and Application on SPOLS*

A quadratic polynomial is a polynomial with the highest of a monomial's term having a degree equal to 2. The standard form is given as $ax^2 + bx + c$, where $a$ and $b$ are coefficients, $x$ is an arbitrary variable, and $c$ is a constant. In this regard, a quadratic polynomial is a fundamental knowledge usually used in other high-level algebra content, such as a quadratic polynomial in several variables' equations or even calculus. One important thing is understanding how to factor a quadratic polynomial, which is the starting skill students can further apply in the high-level calculating process. The textbook [25] based on Thailand's newly revised curriculum of B.E.2560 (A.D. 2017) proposed three methods in factoring polynomials such as using distributive property, factorization of quadratic polynomials in one variable, and using identities of quadratic polynomials. Distributive property can be used as polynomial distribution, for example, $2x(x+y) = 2x^2 + 2xy$. In contrast, to do factorization, the opposite way will be implied. Students must write two or more polynomials in the form of factors multiplied by each other, such as $2y + 4xy = 2y(1+2x)$ since 2 and $y$ is a common factor of $2y$ and $4xy$. The second method, factorization of quadratic polynomials in one variable, is the method that obtains two polynomials multiplication, such as $x^2 + 5x + 6 = (x+2)(x+3)$, students determine the factor of the first term, which is $x$ since $x^2 = x \times x$, then the factors that have summation and product corresponding to the second and third term of the given polynomial that is 2 and 3. Since $2 + 3 = 5$, that is the constant of the second term, while $2 \times 3 = 6$, that is the constant of the third term. The last method uses identities of quadratic polynomials related to two forms named perfect square and difference of perfect square. The perfect square polynomial is given as $a^2 \pm 2ab + b^2$ that factorizing equals to $(a \pm b)^2$ while the difference of the perfect square is given as $a^2 - b^2$ which have $(a+b)(a-b)$ as the factors.

Content ordering starts with numerical factorization in three forms (i.e., a product of whole numbers, distributive property, and the product of the summation of two digits). Then, in a quadratic polynomial $ax^2 + bx + c$, the factorization content was separated into five sub-lessons, covering the polynomial that the coefficient of $x^2$ equals to one or more, the coefficient of $x$ is a positive and negative integer, and the constant c is a positive and negative integer. The reason behind this sequencing is an attempt to grow an understanding of factorizing in mathematics from primitive knowing to property noticing [26]. Scholars suggested that teaching the multiplication of two-digit numbers using base ten blocks can connect to the multiplication and somewhat to the factorization of quadratic polynomials [8]. So, the first lesson developed factorized learning materials by holding the central concept of a basic whole-number multiplication, which expands to polynomial multiplication with action in arranging algebra tiles in a rectangular shape which its area can model the product of two numerals or even two-term (width and length) with a difference propositional logic. However, the system provides different learning materials regarding learning style but is still parallel in content knowledge—examples of some learning materials in each sub-lesson are provided in Fig. 8.

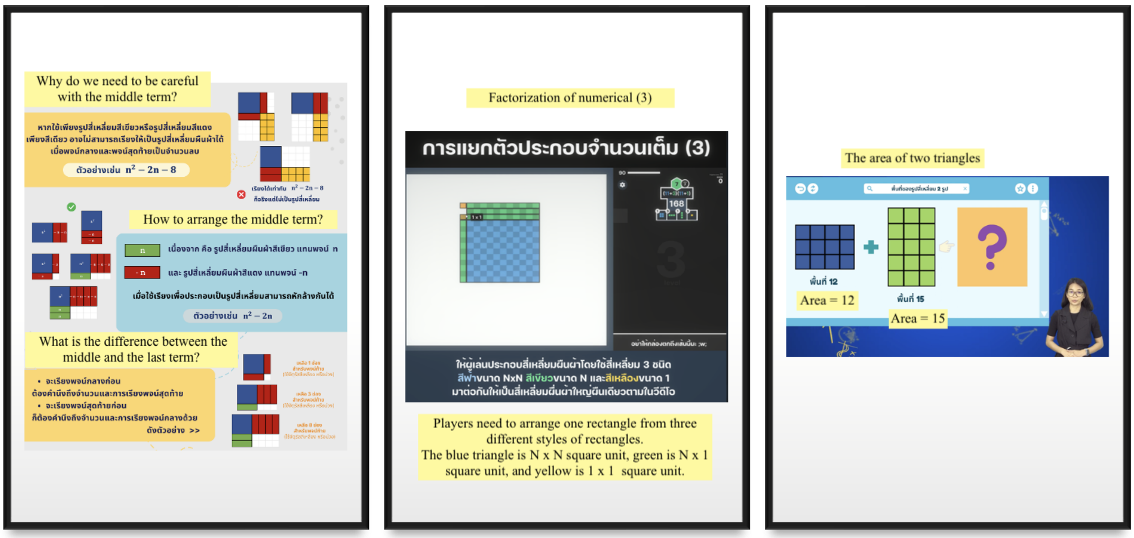


Diagram-based content — Digital game — VDO lecture-based content

Fig. 8. Example of learning materials.

## V. Evaluation and Reflection

### A. Research Methodology

Through the third phase of EDR, Evaluation-Reflection, this study implemented SPOLS into mathematics classrooms to enhance ability in factoring a quadratic polynomial and promote SRL ability. It aims at Thai high school students; therefore, 87 students enrolled in this study during the first break semester of 2022, around a month. All participants studied this topic before to avoid bias on the content difficulty of system use. During involving learning activities (Fig. 9) in SPOLS, students went through the system, including setting learning goals, performing in learning material, taking pre- and post-achievement tests, and self-evaluating learning performance, along with rating their perception on technology acceptance questionnaires before and after using SPOLS. Regarding research ethics clearance guidelines, participants were explained on the investigation activities and provided informed consent, with assurance that their names and identifying information would remain confidential.

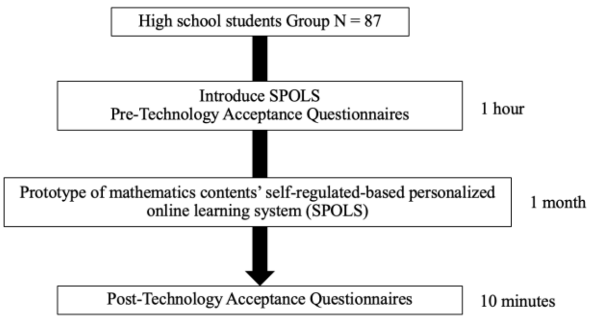


Fig. 9. Research methodology.

As mentioned, the student's perceptions of using SPOLS were gathered through the technology acceptance questionnaires. This study used the Thai version of perception questionnaires with 0.91 Cronbach's α value [22], which was adopted from the original version of Teo's questionnaires [27]. The eleven items with a 5-Likert scale rating from 1, "strongly disagree," to 5, "strongly agree," are used to cover four cohorts. There are three items for Perceived usefulness (PU), Perceived Ease of Use (PEU), and Attitudes (ATT). And another two for Behavior Intention (BI). Considering the measure-item meaning in each construct, firstly, PU is the part where students reflect on the benefits of using SPOLS in support, efficiency, and increased quality resulting in learning mathematics factorization. Secondly, PEU aims to measure students' level of use of SPOLS effortlessly, so all perception rates show the ability to understand and use SPOLS in an understandable, straightforward manner; likewise, it responds to students' target setting in learning mathematics factorization. Thirdly, ATT is a part that shows the attitude toward using SPOLS. Therefore, students' perception levels can reflect enjoyment and attraction and how much they value using SPOLS as a learning tool for factorization in mathematics. Lastly, BI is the construct that mainly tests the continuous use of the SPOLS in learning factorization in class or even in the future.

Regarding research question 1, the students were first asked to rate their perceptions of any online system to learn mathematics. After learning through SPOLS, they were asked to rate the perception again to confirm the value of features in SPOLS.

### B. Hypotheses Setting

Although several studies conducted POLS in mathematics, few scholars found out about the students' acceptance of using POLS, particularly those integrated with self-regulation. Therefore, this study investigates factors influencing system acceptance to confirm that SPOLS reaches the primary expectation for shifting SRL through using SPOLS for learning quadratic polynomial factorization. Regarding the research question 2, Fig. 10 presents the research model to generate the following the hypothesis:

**H1:** Perception of usefulness in using SPOLS for learning mathematics factorization will be influenced by the ease of SPOLS usage.

**H2:** Attitude about using SPOLS for learning mathematics factorization will be influenced by perceptions of the usefulness and ease of use of SPOLS.

**H3:** Behavior intention to use SPOLS for learning mathematics will be influenced by attitudes toward SPOLS.

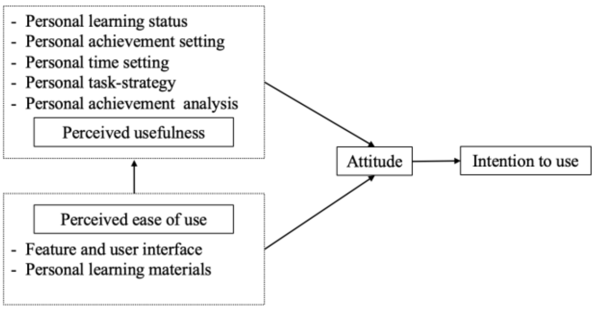


Fig. 10. Conceptual model of research hypothesis setting.

## VI. Results

### A. Comparison of Online Learning System Acceptance Distribution

Regarding research question 1, this study performs a Chi-square test to see the relationship of system acceptance between before and after using SPOLS for learning factorization in mathematics, as represented in Table 2. Three items are statistically significant: PU1, PU3, and BI1. Considering the items, PU1 is about the perception that using SPOLS can improve learning mathematics in quadratic factorization. The result is that $\chi^2$ (2) = 6.33, $p$ = 0.04, and the strength of association is 0.191. It shows a statistically significant association between before and after using SPOLS; that is, after using SPOLS, students perceived a higher level of support for learning the factorization. For PU3, the test item considers SPOLS supportive of learning factorization in mathematics achievement. The chi-square value is $\chi^2$ (2) = 6.93, $p$ = 0.03, and the strength of association is 0.200. These results show that, after using SPOLS, students perceived that it encouraged them to increase their learning achievement. And lastly, with BI1, their future behavior of using SPOLS for learning mathematics factorization, this item reveals $\chi^2$ (3) = 7.92, $p$ = 0.05, and the strength of association is 0.213. However, this item shows how students prefer re-using the general mathematics online learning system over SPOLS. In contrast with other perception constructs (e.g., perceived ease of use, attitude), it was simply to say that both available online learning systems and SPOLS were preferred for learning mathematics by students.

Table 2. Perception distribution comparisons between before and after participating in SPOLS (In parenthesis: After SPOLS)

| Items | Learning Perception | | | | | $\chi^2$ | $p$ |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | |
| PU1 | 0 (0) | 0 (0) | 6 (12) | 56 (40) | 25 (35) | 6.33 | 0.04* |
| PU2 | 0 (0) | 0 (0) | 7 (7) | 49 (40) | 31 (40) | 2.05 | 0.36 |
| PU3 | 0 (0) | 0 (0) | 7 (13) | 52 (35) | 28 (39) | 6.93 | 0.03* |
| PEU1 | 0 (0) | 1 (0) | 13 (10) | 42 (45) | 31 (32) | 1.51 | 0.68 |
| PEU2 | 0 (0) | 0 (1) | 11 (17) | 44 (39) | 32 (30) | 2.65 | 0.45 |
| PEU3 | 0 (0) | 0 (0) | 15 (12) | 38 (33) | 34 (42) | 1.53 | 0.47 |
| ATT1 | 0 (0) | 0 (1) | 6 (15) | 48 (36) | 33 (35) | 6.63 | 0.09 |
| ATT2 | 0 (0) | 1 (2) | 9 (13) | 49 (46) | 28 (26) | 1.23 | 0.75 |
| ATT3 | 0 (0) | 0 (4) | 7 (13) | 45 (43) | 35 (27) | 6.88 | 0.08 |
| BI1 | 0 (0) | 1 (5) | 10 (20) | 51 (38) | 25 (24) | 7.92 | 0.05* |
| BI2 | 0 (0) | 1 (4) | 14 (17) | 44 (36) | 28 (30) | 2.96 | 0.40 |

* $p < 0.05$

### B. Stepwise Multiple Regression for the Path Associated with the Variables

Regarding research question 2 focusing on hypothesis testing, this study first computed Cronbach's α to see the internal consistency of each item, as presented in Table 3. It was found that Cronbach's α value ranged from 0.55 to 0.74, reflecting the acceptable reliability of the items in this study.

Moreover, the Pearson correlation coefficients of the proposed variables were tested. All results showed a value less than 0.90 (Table 4), significantly correlated to others. Therefore, stepwise multiple regression was accomplished to test all the proposed hypotheses to ensure factors influencing SPOLS acceptance.

At the same time, the path associated with the variables, Perceived Usefulness (PU), Perceived Ease of Use (PEU), Attitude (ATT), and Behavior Intention to use (BI) toward SPOLS for learning factorization in mathematics, was also found. As shown in Table 5, the regression analysis for testing H1 is an effect of PEU, an independent variable, on PU, a dependent variable. PEU statistically significantly predicts PU; $F$ (1, 85) = 54.875, $p$ = 0.000, $R^2$ = 0.39. It adds statistically, especially to the prediction, $p < 0.05$.

For testing H2, the effect of PU and PEU on ATT, the finding indicates that after using the SPOLS result, PU and PEU also statistically significantly predict ATT at $p < 0.05$, $F$ (2, 84) = 45.464, $p$ = 0.000 with the $R^2$ of PU and PEU, 0.44 and 0.52, respectively. It is simply to say that after using SPOLS, PEU is the most significant contributor to ATT, at about 52%.

And lastly, to test H3, which aims to evaluate the effect of ATT on BI, the result reveals that ATT statistically significantly predicted BI with $F$ (1, 85) = 83.042, $p$ = 0.000, $R^2$ = 0.49. It is to say that ATT is a more prominent contributor to BI, with about 49%.

Using SPOLS to learn quadratic polynomial factorizations from all testing results indicates a more extensive prediction in all three proposed hypotheses. Significantly, the Perceived Ease of Use (PEU) of SPOLS for learning quadratic factorization was the most significant predictor of positive impact on Attitude (ATT) toward using SPOLS for learning among all hypothesis settings.

Table 3. The corrected item-total correlation of item reliability for the four constructs

| Constructs/items | Corrected item-total correlation |
|---|---|
| PU1 | 0.67 |
| PU2 | 0.68 |
| PU3 | 0.70 |
| PEU1 | 0.58 |
| PEU2 | 0.64 |
| PEU3 | 0.55 |
| ATT1 | 0.66 |
| ATT2 | 0.69 |
| ATT3 | 0.74 |
| BI1 | 0.69 |
| BI2 | 0.72 |
| Overall Cronbach's α value | 0.91 |

Table 4. The Pearson correlation analyses among the four variables using SPOLS for learning factorization in mathematics

| Duration | Variables | PEU | ATT | BI |
|---|---|---|---|---|
| After | PU | 0.63* | 0.66* | 0.59* |
| | PEU | | 0.64* | 0.60* |
| | ATT | | | 0.70* |

* $p < 0.005$

Table 5. The analysis of stepwise multiple regression using SPOLS for learning factorization in mathematics

| Hypotheses | Variable | | β | $R^2$ | $p$ |
|---|---|---|---|---|---|
| | Dependent | Independent | | | |
| H1 | PU | PEU | 0.66 | 0.39 | 0.00* |
| H2 | ATT | PU | 0.47 | 0.44 | 0.00* |
| | | PEU | 0.43 | 0.52 | 0.00* |
| H3 | BI | ATT | 0.57 | 0.49 | 0.00* |

* $p < 0.05$

## VII. Discussions

### A. Perceptions of Students and Factors that Influence Their Intention to Use SPOLS

From the finding results in Table 2, a descriptive statistic showed students' perceptions of the general online learning system (from their experiences) before and after using SPOLS for learning factorization in mathematics. However, there are slightly increasing means of perceptions from pre- to post-using SPOLS (i.e., PU1 and PU3). The chi-square test was performed to reveal the statistical significance of PU1 ($p = 0.04 < 0.05$) and PU3 ($p = 0.03 < 0.05$). It indicates that students perceived the usefulness of using SPOLS for learning factorization in mathematics compared to their previous experience using other systems. In contrast, PEU's overall mean after participating in SPOLS showed a slight increase, and the chi-square results reveal no significance of variation between pre- and post-using SPOLS. These perceptions' results barely reflected that students tend not to feel effortless using SPOLS despite accepting its usefulness based on statistical value. One of the reasons might be affected by the benefits of those designed features and interfaces in SPOLS, including goal setting, learning materials, and learning summaries. As mentioned in Section IV, the students were asked to complete information on the goal-setting page to allow the further process in the SPLOS. They might be confused without guidance for setting the proper goal. As with learning materials, students were allowed to participate with two materials corresponding to their learning preferences. However, to complete the lesson, the system detects students' learning paths involving the learning materials. The students understood that participating in just one material is enough to finish learning tasks. This issue led them to miss taking the post-test, affecting the reporting of their learning performance. With this, the system should be improved to be easier to access, such as providing a tutorial of use in each step or showing a progress bar to remind them which part needs to be completed. Learning materials should be free for students, whether one or two materials they are interested in since the content is still the same.

Nonetheless, it is too rushed to conclude that integrating SRL strategies did not help learn mathematics through personalized online learning but is still not outstanding compared to other available online learning systems that students are used to. Focusing on the SPOLS, the three running sub-items that have been rated most for PU and PEU components are PU2, PEU3, and PU3. First, it is meaningful to students who perceive SPOLS as an assisting learning tool for improving their learning efficiency in mathematics factorization. Secondly, they perceived SPOLS as an easy-to-use system; thirdly, they perceived SPOLS as an assisting learning tool for increasing the quality of their learning achievement in quadratic polynomial factorization. On the other hand, students' perceptions of Attitude (ATT) and Behavior Intention to use (BI) show a decrease in the overall mean scores after using the SPOLS. The mean score of ATT after using SPOLS is 4.13, while that at the beginning is 4.28. The Chi-square results show no statistical significance of variation from pre- to post-using the SPOLS, indicating that students' attitudes towards using SPOLS are as perceptible as using existing online learning systems to learn mathematics.

Additionally, the mean score of the overall BI after using SPOLS is 3.99, while before using SPOLS, it was 4.14. It seems that students have less intent to use SPOLS compared to the existing systems they have experienced. However, there was one sub-item (BI1) that showed a statistically significant variation from pre- to post-using the SPOLS ($p < 0.05$), suggesting that the students' willingness to use the SPOLS is higher than that of existing systems for learning mathematics. These results correspond to previous scholars who studied the acceptance of using personalized e-learning systems through science, technology, and mathematics courses [4]. This study's result revealed that secondary students rated their perception of attitude and intention to use the system less highly than perceived usefulness and ease of use. The minor score-rated items are about the perception of using the learning system to support their learning in the future, like in this study. This issue considers that even students perceive the system as valuable and easy to use for learning mathematics, but this might not significantly affect their attitude and operating behavior. It makes sense for personalized online learning systems for learning mathematics to be concerned more about the features that contributed to their attitude and intention to use them.

Even though this study slightly focuses on attitudes toward using SPOLS in learning factorization, it is hard to deny that content consisting of SPOLS is also one factor that affects students' perceptions. Thus, attitudes toward mathematics should be thought about. A previous study stated that attitude toward mathematics was related in two parts: affective (e.g., liking, passion) and cognitive (e.g., achievement, grade). The Attitudes Toward Mathematics Inventory (ATMI) categories consisted of enjoyment of mathematics, motivation to do mathematics, self-confidence in mathematics, and perceived value of mathematics [28]. So, SPOLS-developed features might consider integrating the abovementioned ATMI subscales with SRL strategies to uplift the perception of use.

According to hypotheses tested using the stepwise multiple correlation techniques, all showed significant relationships among the four variables, as summarized in Fig. 10. The results after using SPOLS for learning mathematics factorization indicate in Table 5 that perceived usefulness is significantly affected by perceived ease of use (H1). The result reveals that the perceived ease of using SPOLS explains 39% of the variability in fostering perceived usefulness. This result reflected an effortless use of SPOLS features in which the provision of personal learning materials matching individual learning styles tended to value SPOLS for learning factorization in mathematics. Along the same line, scholars studied using an intelligent tutoring system to provide personalized mathematics problems, which showed more performance and efficiency, obtained interest, and evoked positive affective responses compared to common problems [2]. It was a means to an adaptive capacity in the technology-based intervention that led students to succeed.

The testing of H2 points out that perceived usefulness and ease of use are predictors of encouraging attitudes toward using SPOLS for learning factorization in mathematics. The finding indicates that perceived usefulness and ease of use slightly explain attitude variability (about 44% and 52%, respectively). So, PEU contributed strongly and considerably to the impact of ATT toward using SPOLS for learning factorization in the overall hypothesis setting. Generally, one might feel comfortable with things that suit their style, including learning. Since ease of use in SPOLS links to the capability to deliver personalized learning material that fits the learning style, these can at least eliminate the lousy attitude toward only learning mathematics through abstract notation forms. Likewise, the study implemented a virtual algebra tile that allowed students to use manipulatives providing geometric figures to gain an understanding of algebra concepts. The results indicated that this intervention increased long-term knowledge retention and learning achievement [9]. Correspondingly, the finding of PU can predict 44%, still bringing a throwback re-thinking about increasing the explicit use of SRL-strategies features that might contribute to a better attitude toward using SPOLS for learning factorization in mathematics. For example, implementing a game-like environment with these features might uplift the willingness to use SPOLS to achieve knowledge while promoting SRL-ability. Since SPOLS allows students to set their preference through SRL-strategies features as they wish, if possible, provide some reference data (i.e., standard time in complete, average learning score), probably urging students to try their best to achieve their goal or resetting to form their new achieve status. For example, pick one SRL strategy to feature in SPOLS, like score and time setting, and then add a game environment like a reaching board that shows the position of a person's achievement compared to the standard score of majorities. It was better than letting students randomly choose some magic number without a reference score. This result is because the learning goal matters with their awareness of the design features, which affect learning outcomes [29].

Nonetheless, the result shows the influence level from attitude to intention to use (H3). The attitude toward using SPOLS can explain 49% of the variability in intent to use. This result emphasized that the better the attitude, the more willingness there is to use SPOLS for learning factorization in mathematics. Likewise, Ajzen and Fishbein's studies stated that one's behavior could be assessed through attitude [30]. The point confirmed that the contribution of attitude should be concurrent with technology and content knowledge. Several learning techniques were applied in mathematics classrooms, whether it be a digital game, peer tutoring approach, social regulation-based online learning, or intelligent tutoring system, always showing a positive influence on behavior and attitude toward mathematics [2, 7, 31–32]. One interesting aspect was the four critical academic mindsets proposed by Farrington and his colleagues, evidenced in students' academic perseverance and academic behaviors increasing well, leading to better learning performance. Four keys were: 1) belonging to the community; 2) ability and competence growing with effort; 3) succeeding at work; and 4) value in work [33]. Thus, to increase the eagerness to use SPOLS, the system interface might consider adding in some technique or characteristic that holds up SRL-strategies features more explicitly and let the student be related to those particular settings rather than define numerical. It can refine SRL's ability and intention to use it.

### *B. The Proposing Model in the Development of SPOLS for Mathematics Learning*

Implementing self-regulated-based personalized online learning is increasingly used among elementary and university participants in various learning contexts to enhance learning outcomes, including cognitive, affective, or technical behavior correlation [10]. However, the scope of research covering mathematics contents will still be less than that of analyzing factors that may influence the usage of SPOLS. This point is critical because those factors reflect students' perception and behavior in use, which also refers to the well-designed and fit-for-purpose nature of that developed self-regulated-based personalized online learning. Therefore, this study seeks out the factors contributing to the strength of SPOLS in learning mathematics factorization. At the same time, the weak parts will be considered and better developed.

In this study, the Technology Acceptance Model [34] was used as the conceptual framework to examine the factors to see the acceptance level using SPOLS in learning factorization in mathematics. Those factors were explained as in the model herewith, PU, which means that for all SRL-strategy features, students received their usefulness for uplifting their SRL abilities through SPOLS for learning factorization in mathematics. With PEU, seen as a provider of personalized learning materials and a system interface, it assists students with easier learning factorization in mathematics via the system and with the appropriate learning material that already fits their learning style. After all, factors were hypotheses tested by stepwise multiple regression of the relations, as shown in Fig. 11. The results relied on three assumptions, of which PEU gave the most prominent predictor ATT, the next inferior predictor for BI. Mapping these findings with the mean score those students rated on TAM questionnaires found that BI got the lowest acceptance level, while ATT got a bit more but was still the third of four constructs. The hypotheses test and rate mean score indicated that increasing BI using SPOLS for learning factorization could first concern ATT while enhancing ATT was to step back to PEU. Therefore, this study presented a summary of the design of a self-regulated personalized online learning system for learning mathematics, as presented in Fig. 12.

Three key elements of SPOLS are SRL strategies, personalized online learning, and Content knowledge. The details were described as follows.

a) Personalized online learning—The online-designed environment means providing instruction based on a personal learning path through personal learning preferences.

b) Content knowledge—An interested content that would like to contribute to the online learning system. In this study, mathematics was selected, especially quadratic polynomial factorization.

c) SRL strategies—One of the learning strategies was a process and tactic that assisted students in managing learning activities or meeting their setting.

d) SRL strategies with personalized online learning system—The combination of activities or actions supporting becoming a regulated person through an online environment that allows participants to choose a suitable learning path based on their learning preference. For example, this study proposes SRL strategy features that ask students to define their priorities and remind them to control themselves until they achieve based on their expectations. However, one concern that should not be overlooked is the ability to stimulate the learning environment to define those SRL strategies for perseverance in achieving goals rather than finishing the content. Therefore, implementing other learning strategies besides SRL might crop up with this weakness, such as game-like features, socially regulated-based, or an academic mindset in regulated behavior.

e) Personalized online learning system with content knowledge—The online environment allows students to acquire knowledge in a particular subject with personal learning instruction corresponding to personal preference. It essentially matches the nature of selected content knowledge. For example, this study provided the learning material for learning factorization in quadratic polynomials. Those materials relied on the learning style; thus, students received suitable ones. However, one point to remember was the subject's nature. Since these learning materials provided the conceptual understanding, there is still a lack of exercise. Thus, the system should later develop to cover the mathematical ability spectrum, from generating conceptual understanding to contributing algebraic sense in the abstract. With this, drill and practice can consider alternative add-ins.

f) Content knowledge with SRL strategies—The use of SRL strategies in supporting learning mathematics until achieved. This section would emphasize handling challenging content knowledge that might drop students off during the learning path. So, attitudes toward content knowledge and SRL strategies are essential to maintaining academic perseverance up to completion. For example, the SRL features allow students to predict achievement scores. At the end of the learning process, the actual scores were displayed with this point, and the system should take some action that contributes to students' re-study if they cannot reach the set goal.

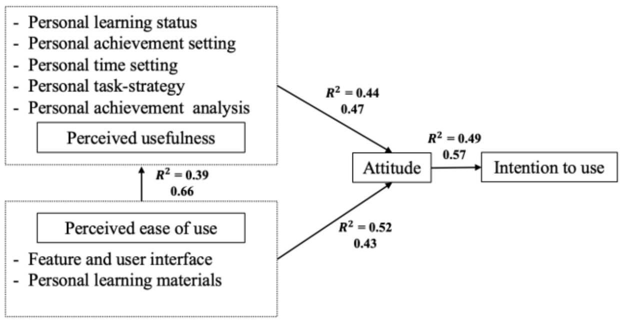


Fig. 11. The result of the hypotheses test after participating in SPOLS.

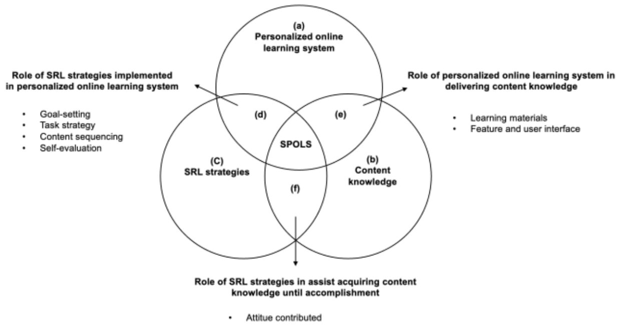


Fig. 12. A designed model for learning through SPOLS.

## VIII. Conclusions

In response to the first research question, the study found statistically significant changes in students' perceptions between previous online learning experiences and SPOLS in PU1, PU3, and BI1. It means that after using SPOLS, students perceived a higher level of support for learning the factorization (PU1) and perceived that SPOLS encouraged them to increase their learning achievement (PU3). In contrast, students prefer re-using the general mathematics online learning system over SPOLS (BI1).

In response to the second research question, the study found that PEU is the most significant contributor to ATT, at about 52%. Meanwhile, ATT is a more prominent contributor to BI, with about 49%. PU also statistically significantly predicts ATT at about 44%. And lastly, PEU statistically significantly predicts PU at 39%. These findings inform researchers to consider those components that might contribute to an effective learning system that should be developed in the near future. With this, the proposed model for developing SPOLS for mathematics learning is suggested for future related work.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

TI conducted, analyzed, and investigated the research and originally drafted the manuscript; PP conceptualized, proposed methodologies, explored the study, reviewed and edited the manuscript; WW investigated the research and reviewed and edited the manuscript. All authors had approved the final version.

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