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Designing E-courseware to Support Vietnamese Students in Self-Study Fractions (4th Grade Mathematics) by Programmed Instruction Method

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The programmed instruction helps each student gain knowledge with different time or sequences, depending on available knowledge, ability, and learning speed. With this method, students can perform self-evaluation and self-regulation in learning activities. This article presents the application of the programmed instruction method in designing the e-courseware to support Vietnamese students in self-review and self-consolidation knowledge related to fractions (4th grade mathematics). The e-courseware was designed with 6 sections: Identifying fractions; Transforming fractions; Comparing fractions; Calculations on fractions; Solving mathematical problems involving fractions; General tests. These sections cover all the knowledge on fractions that a 4th grade student in Vietnam is required to gain. This e-courseware was appraised by experts and primary school teachers for its quality and feasibility. The quantitative analysis method on scores of forty 4th grade students from 2 primary schools was utilized to clarify the effectiveness of the e-courseware. The results indicated that aspects related to the quality and feasibility of the e-courseware were assessed on the high level. In addition, the use of the e-courseware designed by programmed instruction method significantly increases learning outcomes on fractions for 4th grade students.

Keywords: mathematics, e-courseware, instruction, fractions, programmed instruction

INTRODUCTION

Teaching method aims to promote positivity of students considers teaching self-study methods as the core. The current teaching is trying to make the transition from passive learning to active self-study, raising the issue of developing self-study skills at a high-level starting from primary school, especially self-study at home.

Programmed instruction is one of the well-known methods with a central instructional focus on individualizing self-study materials that are centered on the learners (Zendler & Reile, 2018) and its potential advantages have been relatively fully discussed (Emurian, 2005; Izzet Kurbanoglu et al., 2006; Jafarizadeh et al., 2017). Programmed instruction is a teaching pedagogy based on the theory of behaviorism (Reynolds & Tan, 2020) in which (1) the division of learning content into small learning units is important, and (2) the monitoring of learning takes place regularly after each unit (Zendler & Reile, 2018).

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It is based on the mastery learning concept: The students must genuinely understand a topic before moving on to the next one (Canton, 2007). Programmed instruction uses principles of shaping, prompting, discrimination training, stimulus fading, and feedback (Jaehnig & Miller, 2007). Its settings offer students the opportunity to complete activities while obtaining instant feedback (Reynolds & Tan, 2020).

In programmed instruction, the learning task is divided into small steps and in each step, students are expected to participate actively to master the task (Lebedeva et al., 2018), or in other words, complicated and difficult learning materials are divided into small and simple units known. Typically, learners are presented with frames (include only the information such as text, diagrams, or images, etc) containing a bit of information and a multiple-choice or short-answer question based on that information. Learners make a response and are immediately informed whether their answer is correct or incorrect, and instruction continues based upon the preceding response (Twyman, 2020). Learning is most effective when it is accomplished with the least time, effort, energy, and resources. Presenting the material in very small increments allows the student to gain knowledge gradually and sequentially from simple to complex, and to notice the logical structure of the content (Stanisavljevic & Djuric, 2013). This method of teaching presents the learning material in the rational and performance sequences (Majeed & Ilankumaran, 2020). Learning with programmed instruction performs better than reciprocal teaching (Zendler & Reile, 2018). The overall positive effects on mastery learning were confirmed by the meta-analysis of Hattie (Hattie, 2012).

Today, with the development of educational technology, programmed instruction is available as educational e-courseware. These e-courseware are digitized in a pre-defined structure and stored on computers or digital devices in order to use for the purposes of teaching (Hanh, 2010; Son, 2012). Most of the e-courseware are generated by multimedia production software (Cui et al., 2019). To develop the e-courseware, an instructional design model for the development of effective teaching and learning materials is important (Sözcü & İpek, 2013). This model should not only address presentation aspects such as the design of navigational structures among hypermedia objects, but also pay close attention to the organization of the content (Ateyeh et al., 2000). Due to its rich media elements, it is dominant in learning resources in the era of digital learning (Cui et al., 2019). As a means of teaching, the e-courseware has been not only tools or instruments to convey information to learners but also having the role of promoting and coordinating teaching activities to help students elicit and dominate knowledge. Teaching with the support of a good e-courseware can make lessons more interesting and understandable, helping students learn better in their own space (Pichitpornchai, 2005) as well as helping them learn to be more accountable for learning tasks to take a more active role in their learning (Giannakos et al., 2014). Programmed instruction materials can enhance the effectiveness of instruction as they have been thoroughly evaluated, reviewed, revised, and reproduced. Evaluation of this type of multimedia instruction has proven the importance of its application at different educational levels (Miloševic et al., 2016; Feeney, 2017; Ikram & Asim, 2019). However, the author found that studies on applying this type of e-courseware which is designed by programmed instruction method in primary schools over the past 5 years are

relatively limited. Therefore, this study desiderates to design with an appropriate model and reevaluate the impact of this form based on the current development of teaching technology in a developing country as Vietnam.

In the current curriculum of primary schools in Vietnam, the contents of fractions have been taught relatively completely from grade 4. In particular, 4th grade students in Vietnam must fully understand the following areas: (1) Early concepts of fractions: simple concepts of fractions, numerators, denominators; reading and writing fractions; relationship between division of natural numbers and fractions; (2) Basic properties of fractions and equivalent fractions; (3) Simplifying fractions, homogenizing denominators of fractions; (4) Comparing fractions: comparing two fractions in case they have same denominators, comparing two fractions in case they have different denominators, comparing fractions to 1, comparing fractions to natural numbers; using the comparison of fractions to sort the order of them; (5) Calculations on fractions: addition, subtraction, multiplication, division; solving mathematical problems involving four calculations on fractions (finding the fraction of a natural number, finding two numbers in case knowing sum or difference and ratio of them); simple mathematical problems involving units of measurement, algebraic factors, geometry, etc (the data of the problems are fractions) (Ministry of Education and Training, 2009). This is really one of the difficult topics to convey by teachers as well as acquire by students. The reality of teaching shows that mathematical problems on fractions have been contents that 4th grade students often entangle many mistakes when solving.

In Vietnam, there have been very few studies on designing the self-study e-courseware by programmed instruction method, especially e-courseware for primary school students. To help narrow that research gap, this study aims to design a useful self-study e-courseware that is suitable for the context of technological advancement in Vietnam, helping 4th grade students to detect and overcome common mistakes, thereby helping them to deepen knowledge and basic skills in solving mathematical problems on fractions.

METHOD

Research Goal and Design

The main focus of the research was to design the e-courseware to support students in self-study fractions (4th grade mathematics) by programmed instruction method. The author designed a comprehensive e-courseware on fractions with the process as shown in Figure 1. This process was developed based on the process to develop a multimedia courseware that was proposed by Ateyeh et al (Ateyeh et al., 2000).

In step 1, the author defined teaching targets and key contents based on (1) instructions for implementing standard knowledge and skills of subjects in primary schools (grade 4) (Ministry of Education and Training, 2009), (2) the mandatory standards of 4th grade mathematics and the minimum standards of primary mathematics (Hoan et al., 2015).

In step 2, there were three major goals as follows: (i) Determining frames for each unit, (ii) Setting up orientations for designing frames in each unit, (iii) Setting up the

branching diagrams for each frame and each unit. In which, the determination of orientations for designing frames was carried out as follows:

(1) Defining requirements that students need to be proficient in each frame ***(Requirements)***: The requirements have been described based on the standard knowledge and skills of subjects in primary schools (grade 4) (Ministry of Education and Training, 2009).

(2) Identifying mistakes that students often entangled in each frame ***(Mistakes)***: It was accomplished with the support of 27 teachers in 6 primary schools who have had seniority in teaching for 4th graders (3 teachers for Topic 1; 7 teachers for Topic 2; 5 teachers for Topic 3; 7 teachers for Topic 4; 5 teachers for Topic 5). The task of each teacher is to list mistakes that students often entangled in all frames of the assigned-unit, our task is to synthesize and classify these mistakes.

(3) Determining a response strategy for each right or wrong choice of students ***(Corresponding responses)***

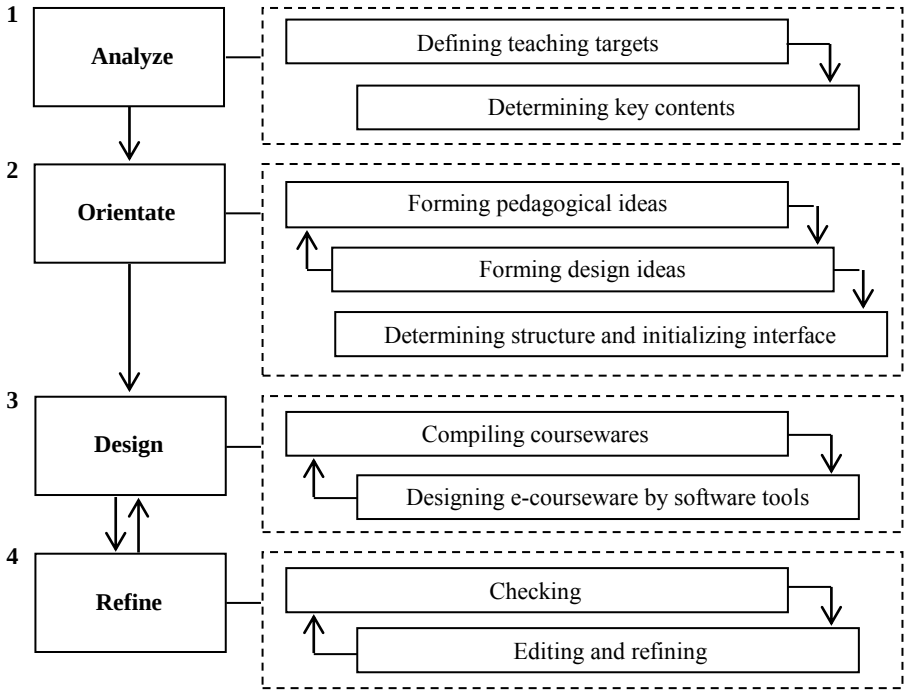


Figure 1
The process used to design the e-courseware

In step 3, the author collected, edited, and designed the coursewares for each frame, and designed the e-courseware system by software tools.

In the last step, the author ran a full inspection and uploaded the e-courseware to the website.

After the design was completed, the author conducted an experiment on 4th grade students to evaluate the effectiveness of the e-courseware (by comparing the mean score between the two post-tests). Earlier, the e-courseware was appraised by experts and primary school teachers for its quality and feasibility. In addition, the author also collected students' responses on the e-courseware through the questionnaires.

Sample and Data Collection

In order to evaluate the effectiveness of the e-courseware, the author conducted an experiment on 40 students from 2 primary schools in Dong Nai province (Trung Vuong Primary School and Song May Primary School). These were two schools in two different regions, one in the downtown and one in the suburbs. In each school, the author selected 20 students with different capacities in maths (excellent, good, average, weak) and divided them equally into 2 groups: the experimental group (E.g) and the control group (C.g). In each group of 10 students, there are: 2 students with excellent capacity, 3 students with good capacity, 3 students with average capacity and 2 students with weak capacity. The 20 students of each school are students who learn in the same environment (in the same class with the same teacher) and will perform the same self-study task. The experimental process was carried out as follows:

- Step 1: Checking the similarity of pairs "E.g - C.g" in 2 schools by the pre-test (Test 1). The test was proceeded after students had finished the lesson "General Practice" (Week 26 of the school year 2018 - 2019).

- Step 2: Assigning the self-study task to students of two experimental groups and guiding them through the manipulations to self-study with the e-courseware (The duration for this task is 1 week).

- Step 3: Talking with the parents of students in two experimental groups about the experimental ideas and asking them for assistance in installing the e-courseware on the private computer at home and give students additional instructions on how to learn with the e-courseware. At the same time, it is recommended that they regularly encourage and remind students to perform the self-study task that was assigned.

- Step 4: Checking the differences of pairs "E.g - C.g" in 2 schools by the post-test (Test 2). The test was deployed as soon as students in the experimental groups completed their self-study task.

Before conducting the experiment on primary school students, the e-courseware was appraised by experts, including: 5 primary education experts, 3 informatics experts. The evaluation was also done by 27 teachers in 6 primary schools who assisted in listing the students' mistakes (at step 2 of the design process). The evaluation results from experts and primary school teachers became the consideration for the e-courseware revision. The instruments used for experts' appraisal, teachers' evaluation were questionnaires. The questionnaire was developed using a 5-point Likert scale (5=Very good, 4=Good,

3=Fair, 2=Poor, 1=Very poor). The questionnaire for evaluation include aspects as shown in Table 1.

Table 1
The aspects used to evaluate the quality and feasibility of the e-courseware

Assessor	Aspects
Informatics experts	- Layout - Accessibility
Primary education experts and primary school teachers	- Suitability with learning objectives - Context/material - Layout - Accessibility - Ability to support self-study

Besides, after conducting the experiment on primary school students. The author also collected responses from students of experimental groups on the e-courseware through the questionnaires. The questionnaire comprised 3 items that were organized on a 5-point Likert scale, as shown in Table 2.

Table 2
The items in the questionnaire for students

Items	Points
I was fun and enjoyable when learning with the e-courseware	5=Strongly agree, 4=Agree, 3=Undecided, 2=Disagree, 1=Strongly disagree
I need reminders from my parents when doing study task	5=Never, 4=Rarely, 3=Sometimes, 2=Often, 1=Always
I need guidance from my parents to master the e-courseware	

Analyzing of Data

The quantitative analysis method was utilized to clarify the effectiveness of the e-courseware. In particular, quantitative analysis assessed the input and output math scores of pairs "E.g - C.g" in 2 schools by the Independent Samples t-Test with a significant level $\alpha = 0.05$ (using SPSS program) to verify the impact on the experimental groups.

With data from the questionnaires (for the experts, primary school teachers, and primary school students), the author calculated the mean score on each aspect or each item and converted to qualitative criteria that were shown in Table 3 (Widoyoko, 2008).

Table 3
Conversion of mean score to qualitative criteria

No.	Mean score ($\overline{X}$)	Criteria
1	$\overline{X} > 4.2$	Very good (or Strongly agree/ Never)
2	$3.4 < \overline{X} \leq 4.2$	Good (or Agree/ Rarely)
3	$2.6 < \overline{X} \leq 3.4$	Fair (or Undecided/ Sometimes)
4	$1.8 < \overline{X} \leq 2.6$	Poor (or Disagree/ Often)
5	$\overline{X} \leq 1.8$	Very poor (or Strongly disagree/ Always)

FINDINGS

The E-courseware Support 4th Grade Students in Self-Study Fractions

The author designed the e-courseware by the four-steps process. The specific results in each step are as follows:

Step 1: Analyze

▪ *Defining teaching targets*

The teaching targets were described as follows:

- Students self-review and self-consolidate the contents of fractions: Recognizing fractions in determined situations *(Target 1);* Reading and writing fractions correctly *(Target 2);* Applying basic properties of fractions to solve math problems *(Target 3)*; Simplifying fractions *(Target 4);* Homogenizing denominators of fractions *(Target 5);* Comparing fractions, comparing fractions to natural numbers *(Target 6);* Accomplishing four calculations on fractions (addition, subtraction, multiplication, division) *(Target 7);* Solving math problems involving four calculations on fractions; Solving simple math problems involving units of measurement, algebraic factors, geometry, etc (the data of problems are fractions) *(Target 8)*.

- Students recognize and correct common mistakes when solving math problems involving fractions; thereby, they can inculcate knowledge and master basic skills related to fractions *(Target 9)*.

▪ *Determining key contents*

Based on teaching targets (identified in step 1), the author determined key contents and classified them into topics and units of knowledge. The results were described in the following table:

Table 4
The table synthesizes topics and units of knowledge in Fractions (Math 4)

Target	Topic	Unit
1, 2, (9)	1. Identifying fractions	1.1. Determining fractions
		1.2. Reading and writing fractions
3, 4, 5, (9)	2. Transforming fractions	2.1. Equivalent fractions
		2.2. Simplifying fractions
		2.3. Homogenizing denominators of fractions
6, (9)	3. Comparing fractions	3.1. Comparing two fractions with the same denominators
		3.2. Comparing two fractions with different denominators
		3.3. Comparing fractions to natural numbers
7, (9)	4. Calculations on fractions	4.1. Addition
		4.2. Subtraction
		4.3. Multiplication
		4.4. Division
8, (9)	5. Solving math problems involving fractions	5.1. Finding the fraction of a natural number
		5.2. Finding two numbers knowing the sum and ratio of them
		5.3. Finding two numbers knowing the differences and ratio of them

Step 2: Orientate

▪ *Forming pedagogical ideas*

First, the author proceed to determine the frames for each unit in Table 4. The results were described in Table 5:

Table 5
The table synthesizes frames in 15 units

Unit	Frame
1.1	F.1: The sum of elements that satisfy the requirement of the mathematical problem (the numerator) is less than the sum of elements that do not satisfy the requirement of the mathematical problem; F.2: The sum of elements that satisfy the requirement of the mathematical problem (the numerator) is greater than the sum of elements that do not satisfy the requirement of the mathematical problem; F.3: Fractions to be determined are not in the lowest terms; F.4: Practical math problems (totality is made up of 1 combination of elements); F.5: Practical math problems (totality is made up of 2 combinations of elements)
1.2	F.6: Reading fraction; F.7: Writing fraction; F.8: Reading a mixture of many fractions F.9: Writing the numerator and denominator from a given-fraction; F.10: Writing fractions in an actual division problem
2.1	F.11: Multiplying both the numerator and the denominator by a non-zero natural number (type 1); F.12: Multiplying both the numerator and the denominator by a non-zero natural number (type 2); F.13: Dividing both the numerator and the denominator by a non-zero natural number (type 1); F.14: Dividing both the numerator and the denominator by a non-zero natural number (type 2); F.15: Identifying equal fractions; F.16: Using properties of fractions to find pairs of equal fractions knowing the numerator (or denominator) of the new fraction; F.17*:* Using properties of fractions to find pairs of equal fractions knowing the numerator (or denominator) of the original fraction; F.18*:* Practicing in synthetic problems
2.2	F.19*:* Simplifying by 1 division (dividing by 1-digit natural number); F.20*:* Simplifying by 2 divisions (dividing by 1-digit natural number); F.21*:* Identifying fraction in its lowest terms (level 1); F.22*:* Identifying fraction in its lowest terms (level 2); F.23*:* Simplifying fractions in a calculation
2.3	F.24*:* Finding common denominator (form 1 - one of the two denominators is divisible by the other denominator); F.25*:* Homogenizing denominators of 2 fractions (common denominator is in form 1); F.26*:* Finding common denominator (form 2 - two denominators are not divisible by each other); F.27*:* Homogenizing denominators of 2 fractions (common denominator is in form 2); F.28*:* Homogenizing denominators for a natural number and a fraction; F.29*:* Homogenizing denominators of many fractions
3.1	F.30*:* Comparing 2 fractions (level 1); F.31*:* Comparing 2 fractions (level 2); F.32*:* Comparing multiple fractions with 1 fraction (using "<"); F.33*:* Comparing multiple fractions with 1 fraction (using ">"); F.34*:* Ordering fractions from smallest to largest; F.35*:* Ordering fractions from largest to smallest
3.2	F.36*:* Comparing fractions (using "<"); F.37*:* Comparing fractions (using ">"); F.38*:* Comparing fractions (using "="); F.39*:* Ordering fractions from smallest to largest; F.40*:* Ordering fractions from largest to smallest; F.41*:* Finding the largest (or smallest) fraction in a group of many fractions; F.42: Practical math problems
3.3	F.43: Comparing fractions to number 1 (using "<"); F.44: Comparing fractions to number 1 (using ">"); F.45: Finding fraction a/b in case $a/b < 1$; F.46: Finding fraction a/b in case $1 < a/b < m/n$; F.47: Comparing fractions to a natural number that is greater than number 1
4.1	F.48: Adding 2 fractions with the same denominators (the result is a fraction in its lowest terms – level 1); F.49: Adding 2 fractions with the same denominators (the result is a fraction in its lowest terms – level 2); F.50: Adding 2 fractions with the same denominators (the result is a fraction is not

	in the lowest terms); F.51: Adding 2 fractions with different denominators (the result is a fraction in its lowest terms); F.52: Adding 2 fractions with different denominators (the result is a fraction is not in the lowest terms); F.53: Adding natural number with fraction; F.54: Adding 3 fractions with the same denominators; F.55: Adding 3 fractions with different denominators; F.56: Solving simple math problems; F.57: Finding x
4.2	F.58: Subtracting 2 fractions with the same denominators (the result is a fraction in its lowest terms); F.59: Subtracting 2 fractions with the same denominators (the result is a fraction is not in the lowest terms); F.60: Subtracting 2 fractions with the same denominators (mixed forms); F.61: Subtracting 2 fractions with different denominators (the result is a fraction in its lowest terms); F.62: Subtracting 2 fractions with different denominators (the result is a fraction is not in the lowest terms); F.63: Subtracting natural number and fraction; F.64: Subtracting 3 fractions with the same denominators; F.65: Subtracting 3 fractions with different denominators; F.66: Solving simple math problems; F.67: Finding x
4.3	F.68: Multiplying 2 fractions (the result is a fraction in its lowest terms); F.69: Multiplying 2 fractions (the result is a fraction is not in the lowest terms); F.70: Multiplying a fraction by a natural number; F.71: Multiplying a natural number by a fraction; F.72: Multiplying a fraction by number 1; F.73: Multiplying a fraction by number 0; F.74: Multiplying 3 fractions; F.75: Solving simple math problems
4.4	F.76: Determining reciprocal fractions; F.77: Dividing 2 fractions (the result is a fraction in its lowest terms); F.78: Dividing 2 fractions (the result is a fraction is not in the lowest terms); F.79: Dividing a natural number by a fraction; F.80: Dividing a fraction by a natural number; F.81: Dividing 2 fractions (mixed forms); F.82: Finding x; F.83: Solving simple math problems
5.1	F.84: How to find the fraction of a natural number; F.85: Finding the fraction of a natural number (simple forms); F.86: Finding the fraction of a natural number (with units of measurement); F.87: Solving math problems (level 1); F.88: Solving math problems (level 2); F.89: Distinguishing math problems involving finding the fraction of a natural number from other types
5.2	F.90: The sum of 2 numbers is given in the "conspicuous" form; F.91: The sum of 2 numbers is given in the "half-conspicuous" form; F.92: The sum of 2 numbers is given in the "non-conspicuous" form
5.3	F.93: The difference of 2 numbers is given in the "conspicuous" form (using the phrase "lesser"); F.94: The difference of 2 numbers is given in the "conspicuous" form (using the phrase "more"); F.95: The difference of 2 numbers is given in the "non-conspicuous" form

The next, the author proceed 3 tasks *(Requirements, Mistakes, Corresponding responses)* that were mentioned in the *Research Goal and Design*. The product of 3 tasks is a detailed table that provides orientations for designing frames in each unit. This table includes orientations for 95 frames. The following table is an example performed on 5 frames in Unit 1.1 (Topic 1):

Table 6
Orientations for designing 5 frames in Unit 1.1 (Topic 1)

Frame 1: *The sum of elements that satisfy the requirement of the mathematical problem (the numerator) is less than the sum of elements that do not satisfy the requirement of the mathematical problem*	
Requirements	Determining the fraction represents colored elements in a diagram that has been divided into equal elements (1)
Mistakes	- M1: Misidentifying numerator (Confusing between colored elements and non-colored elements) - M2: Misidentifying denominator (Determining denominator is the sum of non-colored elements)
Corresponding responses	- R1: (1) Notifying mistake; (2) Providing instructions for determining: Sum of equal elements of diagram, sum of colored elements; (3) Displaying the gate request; (4) Displaying the corresponding content of the textbook before allowing the move to the next request

	- R2: (1) Notifying mistake; (2) Providing instructions for determining: Sum of equal elements of diagram, sum of colored elements, sum of non-colored elements; (3) Displaying the gate request; (4) Displaying the corresponding content of the textbook before allowing the move to the next request
Frame 2: *The sum of elements that satisfy the requirement of the mathematical problem (the numerator) is greater than the sum of elements that do not satisfy the requirement of the mathematical problem*	
Requirements	Determining the fraction represents colored elements in a diagram that has been divided into equal elements (2)
Mistakes	(Same as the mistakes in Frame 1)
Corresponding responses	(Same as the corresponding responses in Frame 1)
Frame 3: *Fractions to be determined are not in the lowest terms*	
Requirements	(1) Determining the fraction represents colored elements in a diagram that has been divided into equal elements (2) Simplifying the fraction
Mistakes	- M1: Misidentifying numerator (Confusing between colored elements and non-colored elements) but simplifying the fraction - M2: Misidentifying denominator (Determining denominator is the sum of non-colored elements) and do not simplify the fraction - M3: Finding the correct fraction but do not simplify this fraction
Corresponding responses	- R1 & R2: (1) Notifying mistake and providing instructions for fixing; (2) Providing sub-requests: Determining the correct fraction (not in the lowest terms), simplifying the fraction; (3) Displaying the gate request; (4) Displaying the corresponding content of the textbook before allowing the move to the next request - R3: Do not give corresponding responses (by do not give answer option)
Frame 4: *Practical math problems (totality is made up of 1 combination of elements)*	
Requirements	(1) Determining the fraction in a factual situation (equal elements are in 1 combination) (2) Simplifying the fraction
Mistakes	- M1: Misidentifying the sum of equal elements of combination (Confusing between the sum of elements that satisfy the requirement of the mathematical problem and the sum of elements that do not satisfy the requirement of the mathematical problem) - M2: Misidentifying the sum of equal elements of combination (Can not separate equal elements of the block that do not satisfy the requirement of mathematical problem) - M3: Finding the correct fraction but do not simplify this fraction
Corresponding responses	- R1 & R2: (1) Notifying mistake; (2) Providing instructions for determining the sum of equal elements of combination; (3) Displaying the gate request; (4) Displaying the corresponding content of the textbook before allowing the move to the next request - R3: Do not give corresponding responses (by do not give answer option)
Frame 5: *Practical math problems (totality is made up of 2 combinations of elements)*	
Requirements	(1) Determining the fraction in a factual situation (equal elements are in 2 combinations) (2) Simplifying the fraction
Mistakes	- M1: Misidentifying the sum of equal elements (Do not realize heterogeneity of equal elements in 2 combinations) - M2: Misidentifying the sum of equal elements (Confusing between the sum of equal elements and the sum of combinations) - M3: Finding the correct fraction but do not simplify this fraction
Corresponding responses	- R1 & R2: (1) Notifying mistake; (2) Providing instructions for determining (with detailed illustrations): the sum of equal elements, the sum of elements that satisfy the requirement of the mathematical problem; (3) Providing instructions for determining (with non-detailed illustrations): the sum of equal elements, the sum of elements that satisfy the requirement of the mathematical problem; (4) Displaying the gate request; (5) Displaying the corresponding content of the textbook - R3: Do not give corresponding responses (by do not give answer option)

▪ *Forming design ideas*

Each frame will be designed to correspond to a basic mathematical form that students need to be revised and reinforced. Ideas for designing them are following: (1) Including many types of questions (multiple choice, fill in blank, matching, drag and drop, short answer, hot spot) aimed at maximizing students' thinking ability and keep them from being bored during the self-study process; (2) Do not allow learners to go back to a previously selected-question, not to move to the next question without choosing an answer option for the question that is being solved. In addition, with each right or wrong choice, the learner will be led to different follow-up questions; (3) After each learner's choice, e-courseware will immediately give feedback to confirm whether the answer is right or wrong and if wrong, how is it wrong. In this way, learners can easily self-consolidate their knowledge; (4) During the operation process in each frame, learners always have the support from the textbook (learners can review the lesson in the textbook related to the frame being solved); (5) The e-courseware will be built in the direction of reviewing, consolidating knowledge firmly, so the start of each frame will be knowledge, the end of the frame is also knowledge (Core knowledge → frames → core knowledge)

Our next task is to set up the branching diagrams for each frame and each unit (Based on the detailed table that provides orientations for designing frames in each unit). The products of this task are the 15 branching diagrams for 15 units. The below diagram is an example performed on the 5 frames in Unit 1.1 (Topic 1).

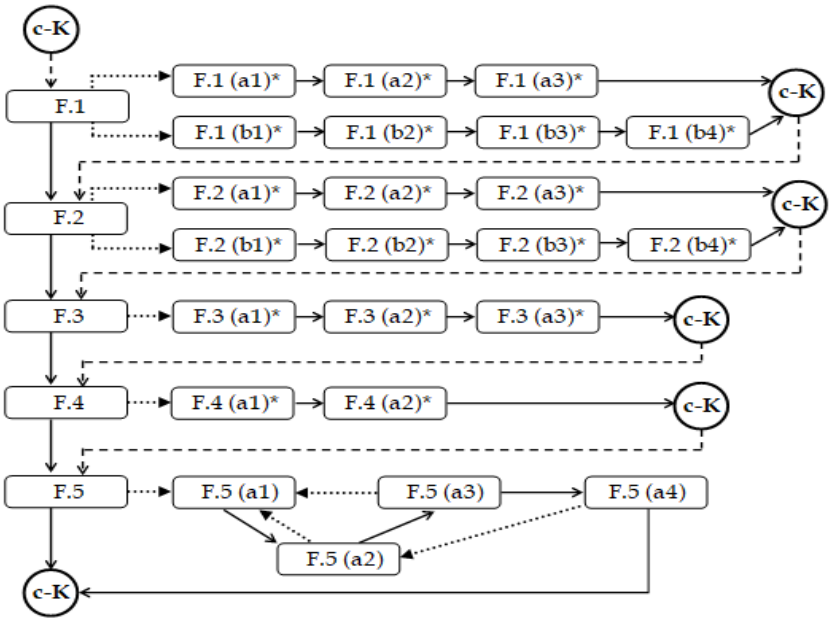


Figure 2
The branching diagram for 5 frames in Unit 1.1 (Topic 1)

Notes: : The direction to go if the answer is correct

: The direction to go if the answer is wrong

: The mandatory direction

*** :** This is a question that is immediately responded to by a separate results table

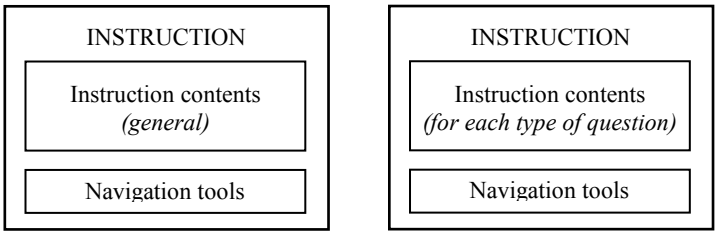
c-K: The core knowledge

▪ *Determining structure and initializing interface*

The structure of e-courseware: The e-courseware is built with 6 sections, in which 5 sections corresponding to 5 topics: Identifying fractions, Transforming fractions, Comparing fractions, Calculations on fractions, Solving mathematical problems involving fractions. The other is General tests.

The interface: The author initialize 3 forms of interfaces as follows:

- The instruction pages:

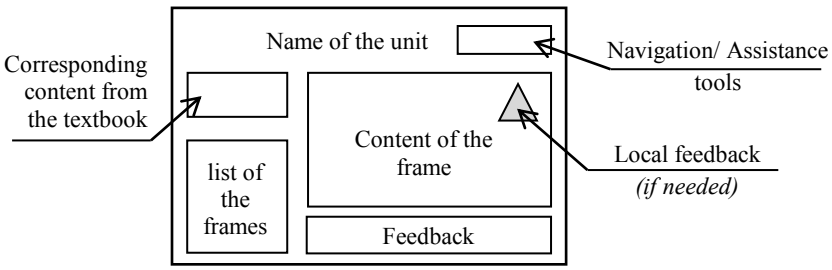


(Displayed before starting to the pages that show the topics)

(Displayed in the units)

- The pages that show the units: Include 3 areas: (1) the area for the topic name, (2) the area for the list of the units, (3) the area for the navigation tools.

- The pages that show the frames:



Step 3: Design

▪ *Compiling coursewares*

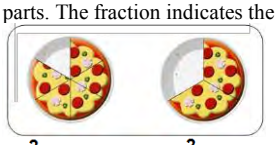
In this step, the author collected, edited, and designed the coursewares for each frame (based on the branching diagrams) and classified them into groups according to the intended use: (1) Mathematical problem files*;* (2) The textbook files corresponding to

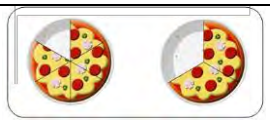
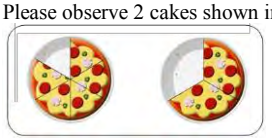
each frame (or unit); (3) Other supporting files (images, sounds, graphics, motions/animations, movies, etc)

▪ *Designing e-courseware by software tools*

The software tool chosen to design the frames and the e-courseware system was Lectora Inspire (Version 16). The first, the author designed questions for each frame and link them to complete this frame. Then, the author linked frames in a unit to complete this unit. The following example is an illustration for designing questions in Frame 5 (Unit 1.1):

Table 7
Questions in Frame 5 (Unit 1.1)

Frame 5		
F.5	Question	Ha has 2 cakes which are divided into parts as shown below. She ate a few parts. The fraction indicates the sum of parts that Ha ate is:  ○ $\frac{2}{9}$ ○ $\frac{2}{2}$ ○ $\frac{1}{4}$
	Feedback for correct answer	Congratulations! You answered correctly You can continue
	Feedback for wrong answers	- Your answer is not correct. Please click the button "Continue" *(Displaying immediately after learner gives an answer option)* - You are mistaken! Please complete the following question *(Displaying when the learner is transferred to frame F.5 (a1))*
F.5 (a1)	Question	Please observe 2 cakes shown in the diagram and tell:  a) Before Ha ate a few parts, how many equal parts were the 2 cakes divided into? ○ **12** ○ **9** ○ **4** b) How many equal parts did Ha eat? ○ **1** ○ **3** ○ **2**
	Feedback for correct answer	Congratulations on completing the questions! You can continue
	Feedback for wrong answers *(Local feedback)*	a) Your answer is not correct. This is the sum of equal parts of the rest! You have to count the sum of equal parts of both cakes that Ha has not eaten (Choose 9). Your answer is not correct. The parts of 2 cake that you have counted are not equal. You have to count the sum of equal parts of both cakes (Choose 4) b) Your answer is not correct.This is the part that Ha ate from the 1st cake. You have to count the sum of equal parts of both cakes that Ha has eaten (Choose 1) Your answer is not correct. The two parts that you have counted are not equal. You have to count the sum of equal parts of both cakes that Ha has eaten (Choose 2)
F.5	Question	Please observe 2 cakes shown in the diagram and tell:

(a2)		 Before Ha ate a few parts, how many equal parts were the 2 cakes divided into? ○ 12 ○ 9
	Feedback for correct answer	Congratulations! You answered correctly You can continue
	Feedback for wrong answers	Your answer is not correct. Please click the button "Continue" *(go back to frame F.5 (a1))*
F.5 (a3)	Question	Please observe 2 cakes shown in the diagram and tell:  How many equal parts did Ha eat? ○ 2 ○ 3
	Feedback for correct answer	Congratulations! You answered correctly You can continue
	Feedback for wrong answers	Your answer is not correct. Please click the button "Continue" *(go back to frame F.5 (a1))*
F.5 (a4)	Question	Please observe 2 cakes shown in the diagram and tell:  The fraction indicates the sum of parts that Ha ate is: ○ $\frac{2}{9}$ ○ $\frac{1}{4}$
	Feedback for correct answer	Congratulations! You answered correctly You can continue
	Feedback for wrong answers	Your answer is not correct Please count again: the sum of equal parts of both cakes and the sum of equal parts of both cakes that Ha has eaten. Remember to simplify the fraction that you find Please click the button "Continue" *(go back to frame F.5 (a2))*

After completing the design of the 15 units, the author proceeded to set up the necessary hyperlinks and design the interface for the e-courseware system.

There are some images of the e-courseware that is designed by programmed instruction method to support 4th grade students in self-study fractions:

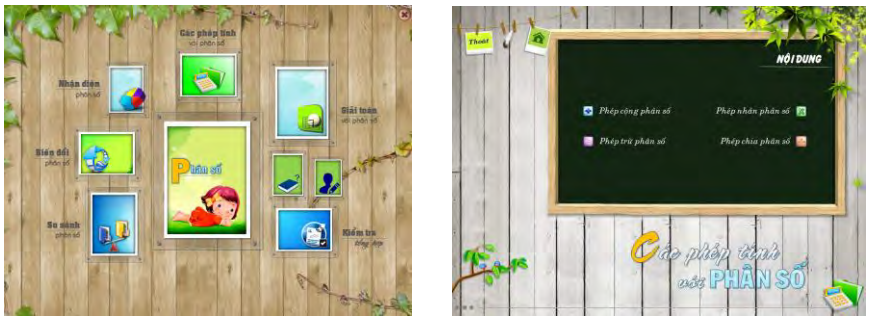


Figure 3
The page shows topics (left) and the page shows units (right)

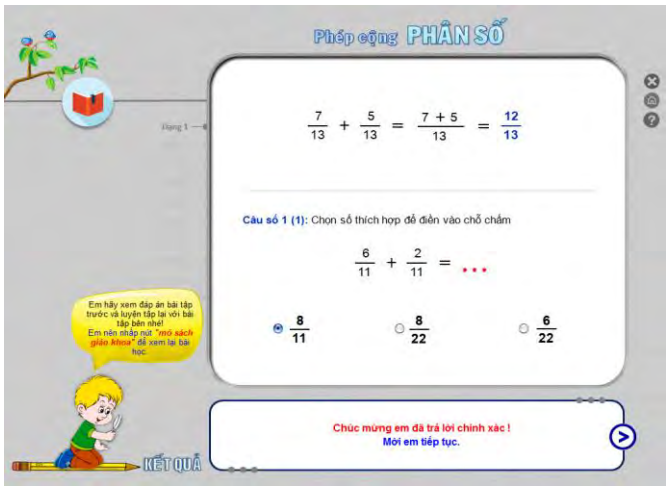


Figure 4
The page shows the frame

Figure 5
The instruction pages

Step 4: Refine

After designing, the author ran a full inspection to check for possible errors and finalize the e-courseware (it was called **F- ecourseware**).

The F-ecourseware has been packaged and uploaded to the website: ***https://hoclieudientu.wordpress.com***.

The Quanlity, Feasibility and Effectiveness of the F-ecourseware

The Quanlity and Feasibility of the F-ecourseware

The F-ecourseware was appraised by experts and primary school teachers for its quality and feasibility. The results are depicted in Table 8.

Table 8
The results from the evaluation of experts and primary school teachers

Assessor	Aspects	Mean	Criteria
Informatics experts	Layout	4.33	Very good
	Accessibility	3.67	Good
Primary education experts	Suitability with learning objectives	4.60	Very good
	Context/material	4.80	Very good
	Layout	3.60	Good
	Accessibility	4.40	Very good
	Ability to support self-study	4.60	Very good
Primary school teachers	Suitability with learning objectives	4.52	Very good
	Context/material	4.63	Very good
	Layout	3.85	Good
	Accessibility	4.48	Very good
	Ability to support self-study	4.74	Very good

The results from Table 8 show that: Aspects related to the quality and feasibility of the F-ecourseware were assessed on the high level, most of them at the Very good. Noteworthily, both primary education experts and primary school teachers rated at the very high level for the Context/material (respectively $\overline{X} = 4.80$ and $\overline{X} = 4.63$) and the Ability to support self-study (respectively $\overline{X} = 4.60$ and $\overline{X} = 4.74$). Two aspects were rated as Good, they were Layout (by primary education experts and primary school teachers) and Accessibility (by informatics experts).

The Effectiveness of the F-ecourseware

In order to evaluate the effectiveness of the F-ecourseware, the author conducted an experiment on 40 students from 2 primary schools in Dong Nai province. The results can be seen in the following tables:

Table 9
Statistical quantities on scores of test 1

					Independent Samples Test				
					Levene's test for equality of Variances		t-test for equality of Means		
	Mean	Min.	Max.	SD	F	Sig.	t	df	Sig.(2-tailed)
Trung Vuong_E.g	6.85	4.00	9.00	1.81	.411	.530	.773	18	.450
Trung Vuong_C.g	6.20	3.50	9.00	1.95					
Song May_E.g	6.35	3.00	8.50	1.90	.058	.812	-.113	18	.911
Song May_C.g	6.45	3.00	9.00	2.05					

The results from Table 9 show that: The difference between the mean values of pairs "E.g - C.g" in 2 schools is not significant. The mean score of pairs "E.g - C.g" is similar. Thus, the pairs "E.g - C.g" in each school have the equal capacity in mathematics. Based on this result, the author proceed to the next steps and the results are as follows:

Table 10
Statistical quantities on scores of test 2

					Independent Samples Test				
					Levene's test for equality of Variances		t-test for equality of Means		
	Mean	Min.	Max.	SD	F	Sig.	t	df	Sig.(2-tailed)
Trung Vuong_E.g	8.85	6.00	10.00	1.56	1.548	.229	3.120	18	.006
Trung Vuong_C.g	6.30	2.50	9.00	2.06					
Song May_E.g	8.60	5.50	10.00	1.65	.539	.472	2.954	18	.008
Song May_C.g	6.15	3.00	9.00	2.04					

The results from Table 10 show that: (1) The difference between the variances in the experimental group and control group (considered in each school) is not significant, (2) The difference between the mean values of pairs "E.g - C.g" in 2 schools is significant. The mean score of the experimental groups was higher than the control groups.

In addition, the author also collected responses from students of experimental groups on the F-ecourseware through the questionnaire that comprised 3 items. The results can be seen in Table 11.

Table 11
The students' responses on the F-ecourseware

No.	Items	Mean	Criteria
1	I was fun and enjoyable when learning with the F-ecourseware	4.45	Strongly agree
2	I need reminders from my parents when doing study task	3.17	Sometimes
3	I need guidance from my parents to master the F-ecourseware	3.70	Rarely

The results from Table 11 show that: Students have positive attitudes towards the self-study e-courseware on 4th grade fractions. Moreover, they do not have much difficulty in manipulating the F-ecourseware. Taking a closer looks at the answers to item 3, the author found that 7 students chose the "Never" point, which means, 35% of them said that they could manipulate the F-ecourseware by themselves without any guidance from their parents.

DISCUSSION

Designing an e-courseware by the programmed instruction method is not too difficult, but in order for the e-courseware to show optimally its support capabilities in teaching, it needs to be designed according to a process in which the pedagogical idea is shown clearly. This study details the steps of designing an e-courseware by programmed instruction method with the aim of providing an illustrative model through which teachers can design own e-courseware by themselves, thereby contributing to improving the quality of teaching and learning in primary schools. Accordingly, it is necessary to carry out a process with four steps to design an e-courseware by the programmed method. In which, the step is considered the most important step is step 2 (Orientate) which has not been fully covered in the design process of many authors, e.g. Ateyeh et al. (2000), Shaik Fathima (2013), Feeney (2017), etc, because the product obtained from this step will determine the content of the programmed instruction e-courseware. In step 2 of the design process, the identification of students' mistakes as well as the corresponding responses should be done in a thorough manner. It is in line with those reported by Mohammed et al. (2019) when they detail two steps (learner analysis and behavior analysis) of the process of building programmed instruction e-courseware. In a suggestion, in this step, the involvement of teachers who have seniority in teaching is essential. It makes the e-courseware more targeted (Sushma N Jogan, 2018). In addition, the selection of software tool is also very important, especially when the designer is a primary teacher. The software tool selected to design the e-courseware system in this study is the relatively easy software to use, Lectora Inspire software. This software provides effective support for designing interactive e-courseware (Mudinillah, 2019). In particular, it makes the process of designing the e-courseware by programmed instruction method quicker and easier, with no a sophisticated understanding of programming languages (Wibawa et al., 2017). This is one of the prominent features of Lectora Inspire software when compared to a similar software tool such as Asymetrix ToolBook that was the easiest authoring software when the content contained more interactive features and the non-programmer authors could develop without programming (Dalgarno, 1998; Pichitpornchai, 2005).

Results from the experiment, appraisal process and students' responses have confirmed the quality, feasibility, and efficiency of the e-courseware that was designed by the programmed instruction method. The results indicated the positive effect of programmed instruction e-courseware on the learning outcomes of students. It is consistent with those reported by Alanazi (2015), Jafarizadeh et al. (2017), and Majeed & Ilankumaran (2020). Programmed instruction e-courseware not only has a positive effect on teaching conceptual knowledge as those reported by Zendler & Reile (2018) but also has a positive effect on reinforcing and deepening the learned knowledge. In addition, the results also showed that the primary school teachers and primary school students in Vietnam have positive attitudes towards the self-study e-courseware on 4th grade fractions, the programmed instruction e-courseware promotes primary school students' interest and activates their cognitive activity (Lebedeva et al., 2018). This is an important indication showing the potential of applying the e-courseware in teaching at primary school. This indication affirms that the primary school teachers and primary school students have the belief in the benefits that the e-courseware can bring. It relates to the Performance Expectancy, one of the four key constructs that influence behavioral intention to use a technology and/or technology use (Venkatesh et al., 2012). This construct has a direct impact on the user's intention to use the e-courseware in teaching, the greater the Performance Expectancy is, the higher the intention to use the e-courseware will be.

CONCLUSION

In this study, the author designed a programmed instruction e-courseware with 6 sections (Identifying fractions; Transforming fractions; Comparing fractions; Calculations on fractions; Solving mathematical problems involving fractions; General tests) to support primary school students in self-review and self-consolidation knowledge related to fractions (4th grade mathematics). The four-steps process was used for development, including: Analyze, Orientate, Design, Refine. This e-courseware that is not too difficult to design has a positive effect on the learning outcomes of primary school students and activates their cognitive activity. Thus, the teachers should be bold in designing suitable programmed instruction e-courseware for their students, and the process proposed by this study should be a consideration to apply. In addition, as mentioned in the introduction, there have been very few studies on designing self-study e-courseware by programmed instruction method, especially e-courseware for primary school students, in Vietnam. With the results from the study, the author found that, in the context of technological advancement in Vietnam, designing self-study e-courseware by programmed instruction method for 4th grade Vietnamese students is completely feasible and brings many positive effects to the teaching process. Therefore, more research is needed in this field. Subsequent studies may develop the e-courseware using the procedures applied herein or assess the effects of the e-courseware that have built up in this study on a larger scale.

REFERENCES

Alanazi, M. S. (2015). The effectiveness of programmed education in developing writing skills of children with learning difficulties in primary education: A case study of

northern border areas of Saudi Arabia. *Journal of Educational and Developmental Psychology*, *5*(2), 39–50. https://doi.org/10.5539/jedp.v5n2p39

Ateyeh, K., Mülle, J. A., & Lockemann, P. C. (2000). Modular development of multimedia courseware. *Proceedings of the 1st International Conference on Web Information Systems Engineering (WISE 2000)*, 179–187. https://doi.org/10.1109/WISE.2000.882878

Canton, R. L. (2007). *Programmed instruction in online learning*. Youngstown, New York: Cambria Press.

Cui, G., Wang, Y., Yu, H., Liu, H., Shibin Liang, S., & Guo, X. (2019). A summarization generation method for e-courseware on the internet platform. *Proceedings - 2019 IEEE Intl Conf on Parallel and Distributed Processing with Applications, Big Data and Cloud Computing, Sustainable Computing and Communications, Social Computing and Networking*, 1416–1420. https://doi.org/10.1109/ISPA-BDCloud-SustainCom-SocialCom48970.2019.00203

Dalgarno, B. (1998). Tools for authoring constructivist computer assisted learning resources: A review. *Australasian Society for Computers In Learning In Tertiary Education Conference (Ascilite)*, 143–153.

Emurian, H. H. (2005). Web-based programmed instruction: Evidence of rule-governed learning. *Computers in Human Behavior*, *21*(6), 893–915. https://doi.org/10.1016/j.chb.2004.03.002

Feeney, R. (2017). Old tricks are the best tricks: Repurposing programmed instruction in the mobile, digital age. *Performance Improvement*, *56*(5), 6–17. https://doi.org/10.1002/pfi.21694

Giannakos, M. N., Krogstie, J., & Chrisochoides, N. (2014). Reviewing the flipped classroom research: Reflections for computer science education. *Proceedings of the Computer Science Education Research Conference*, 23–29. https://doi.org/10.1145/2691352.2691354

Hanh, B. T. (2010). *Applying information and communication technology in teaching organic chemistry in colleges and universities*. Doctoral Thesis in Education, Hanoi National University of Education.

Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*. New York: Routledge.

Hoan, D. D., Ang, N., Chung, V. Q., Dat, D. T., Hieu, D. T., Hien, T. D., & Lai, D. T. (2015). *Mathematics 4*. Hanoi: Vietnam Education Publishing House.

Ikram, I., & Asim, M. (2019). Correlation between programmed learning and metacognition: A study on experiential learning perspectives of secondary school teachers. *International Journal of Experiential Learning & Case Studies*, *4*(2), 332–345. https://doi.org/10.22555/ijelcs.v4i2.2757

Izzet Kurbanoglu, N., Taskesenligil, Y., & Sozbilir, M. (2006). Programmed instruction revisited: A study on teaching stereochemistry. *Chemistry Education Research and Practice*, *7*(1), 13–21. https://doi.org/10.1039/b5rp90012c

Jaehnig, W., & Miller, M. L. (2007). Feedback types in programmed instruction: A systematic review. *The Psychological Record*, *57*, 219–232.

Jafarizadeh, H., Rahmani, A., Habibzadeh, H., Amiri, S., Moghaddam, A. S., & Moradi, Y. (2017). The effect of blended training (programmed and lecture-based training) on learning health status assessment course among nursing students. *Bali Medical Journal*, *6*(3), 606–610. https://doi.org/10.15562/bmj.v6i3.688

Lebedeva, O., Bykova, S., Masalimova, A. R., Sokolova, N. L., & Kryukova, N. I. (2018). Peculiarities of developing high school students' lexical skills by means of the programmed learning technology. *XLinguae*, *11*(1), 186–202. https://doi.org/10.18355/XL.2018.11.01.16

Majeed, C. T. A., & Ilankumaran, M. (2020). Programmed instruction: A research based system for learning language skills. *Journal of Xi'an University of Architecture & Technology*, *12*(8), 909–920.

Miloševic, D., Bibic, L. I., Dukicin, S., Džigurski, A. I., & Ristanovic, B. (2016). The possibilities of application of programmed instruction in the sixth grade of the second cycle of education in accordance with standards. *Geographica Pannonica*, *20*(2), 96–104. https://doi.org/10.18421/GP20.02-01

Ministry of Education and Training. (2009). *Instructions for implementing standard knowledge and skills of subjects in primary schools (grade 4)*. Hanoi: Education Publishing House.

Mohammed, M., Rodger, S., & Shaffer, C. A. (2019). Using programmed instruction to help students engage with etextbook content. *CEUR Workshop Proceedings*, *2348*, 146–156.

Mudinillah, A. (2019). The development of interactive multimedia using lectora inspire application in Arabic language learning. *Jurnal Iqra': Kajian Ilmu Pendidikan*, *4*(2), 285–300. https://doi.org/10.25217/ji.v4i2.570

Parrott, L., & Kok, R. (1997). Design and development of multimedia courseware: An overview. *Canadian Agricultural Engineering*, *39*(2), 131–137.

Pichitpornchai, C. (2005). Research and development of CAIBuilder: An innovative authoring tool for creating e-courseware easily. *Siriraj Medical Journal*, *57*(6), 182–192.

Reynolds, J. L., & Tan, D. (2020). The flipped computer science classroom: A modern approach to programmed instruction. In Z. Walker, D. Tan, & N. K. Koh (Eds.), *Flipped classrooms with diverse learners* (pp. 135–148). Singapore: Springer.

Shaik Fathima. (2013). Thinking of programmed instructional design: Need of today's learner. *International Journal of Modern Engineering Research*, *3*(2), 1056–1060.

Son, P. N. (2012). *Applying information technology in teaching organic chemistry at high school to improve the quality of teaching.* Doctoral Thesis in Education, Hanoi National University of Education.

Sözcü, Ö. F., & İpek, İ. (2013). Considerations for IEL courseware design and the next generation of e-learning. *European Journal of Contemporary Education*, *6*(4), 204–214. https://doi.org/10.13187/ejced.2013.6.204

Stanisavljevic, J., & Djuric, D. (2013). The application of programmed instruction in fulfilling the physiology course requirements. *Journal of Biological Education*, *47*(1), 29–38. https://doi.org/10.1080/00219266.2012.753103

Sushma N Jogan. (2018). Design of branching programmed software material in teaching of English. *Research Review International Journal of Multidisciplinary*, *3*(8), 898–902.

Twyman, J. S. (2020). Programmed instruction. *The Encyclopedia of Child and Adolescent Development*, 1–11. https://doi.org/10.1002/9781119171492.wecad095

Venkatesh, V., Th, J. Y. L., & XinXu. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly*, *36*(1), 157–178. https://doi.org/10.2307/41410412

Wibawa, S. C., Harimurti, R., & Y. A., & Sumbawati, M. S. (2017). The design and implementation of an educational multimedia interactive operation system using Lectora inspire. *Elinvo*, *2*(1), 74–79. https://doi.org/10.21831/elinvo.v2i1.16633

Widoyoko, S. E. P. (2008). The development of social science learning quality and output evaluation model in junior secondary school. *Jurnal Penelitian Dan Evaluasi Pendidikan*, *11*(1), 40–54.

Zendler, A., & Reile, S. (2018). The effect of reciprocal teaching and programmed instruction on learning outcome in computer science education. *Studies in Educational Evaluation*, *58*, 132–144. https://doi.org/10.1016/j.stueduc. 2018.05.008