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The Development of Problem-Solving Competence Assessment Standards in Math for Vietnamese Students

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Abstract

Applying the 'From Assessment to Policy' model of Assessment and Teaching 21th Century Skills (ATC21S) Project, 'Construct Modeling' of Berkeley Evaluation and Assessment Research (BEAR), 'Competence Developmental Progress' by Robert Glaser and Item Response Theory (IRT), we set up a hypothetical Problem-Solving Competence (PSC) developmental progress and sketched out the PSC assessment standards, established PSC measurement tasks, and described outputs. We collected real PSC evidence based on cross-sectional study models; then adjusted the developmental progress and PSC assessment standards accordingly. As geared toward Vietnamese students, PSC is comprised of 4 elements. These are: explore problem, establish problem space, plan and execute solution, and assess and reflect on the solution together with 15 corresponding behaviors. The PSC developmental progress and its elements are categorized into five different levels in order to help build assessment standards in math for senior students of primary schools, as well as lower and upper secondary schools. The measurement results from 900 students in the Vinh Phuc, Nghe An, Dak Lak provinces show that the PSC developmental progress and the assessment standards are suitable for Vietnamese students; the challenge is how to build sound PSC benchmarks that are feasible for development of school curricula in Vietnam.

Key terms: *Problem-solving competence; competence assessment; competence assessment standards, competence-based curriculum; outcome standard*

1. Introduction

Generally, despite having a good academic basis, Vietnamese students lack critical abilities, problem-solving skills and creativity. Therefore, there are urgent requirements to renovate the school curricula, textbooks and especially the methods used to assess students' abilities (National Assembly of the Socialist Republic of Vietnam, 2014).

"All Life Is Problem Solving", a book by Karl Popper, emphasizes the importance and frequency of problems individuals face in life (Popper, K., 2001). The development of key competencies in general, and the Problem-Solving Competence (PSC) in particular, changes the educational process from focusing on knowledge to focusing on what students need to know and are able to do within many different contexts. This will lead to a change in outcome quality for the education system; specifically, from passive to active states based on competence theory. This change in the educational process will help to create a positive impact on each individual, which will contribute to Vietnam's economic development and improved global position as a result.

From traditional viewpoints PSC can be approached through a problem-solving process and a shift in perception once the problem is solved (Polya, G., 1957). From modern standpoints, PSC can be approached through information processing with an emphasis on the problem solver's thought process or the "information processing system," the problem, and the problem space. The term *problem space* refers to psychological changes of the problem solver including the original state (known information), intermediate state (information connecting the original state to the targets), desired state (goals), methods, and action strategies to move from one state to another (OECD, 2010). While PISA 2003 studied the PSC's focus on analyzing problem solving, or "*an individual's capacity to use*

cognitive processes to resolve real, cross disciplinary situations where the solution path is not immediately obvious" (OECD, 2003), PISA 2012 focused on personal interaction with the problem, which is characterized by the dynamic interaction between problem solver and problems to generate and integrate information about the problems (Greiff, S., Holt, D. V., and Funke, J., (2013). Meanwhile, the Assessment and Teaching of 21st century Skills (ATC21S) project concentrated on cooperation among individuals with problems (Griffin, P., McGaw, B. and Care, E., 2012).

Results from these research studies have helped many countries, including Australia, Canada, Singapore, and New Zealand to develop the PSC for students by integrating it into the educational curriculum. First, a competence developmental progress is established and used to construct the assessment standards; then, it is implemented in teaching and assessment (ACARA, 2015, New Zealand Ministry of Education, 1997, Adamson, F. and Darling–Hammond, L., 2012).

Competence developmental progress describes the path/map that learners can take in the process of mastering learning skills. Theo Patrick Griffin, Barry McGaw, Esther Care (2012), the competence developmental progress should be based on four main factors: learning targets, progress variables, levels of achievement, and learning performances. It sketches out future pathways for learner's progress.

Different levels of the competence developmental progress that are considered the competence assessment standard for each subject demonstrate what students need to know and what they can do with the content of each subject. For example, in Australia's curriculum, the PSC is integrated into critical and creative thinking capabilities. Its learning progress is organized into four interrelated elements, each detailing different aspects of thinking: i) Inquiring–identifying, exploring and organizing information and ideas; ii) Generating ideas, possibilities, and actions; iii) Reflecting on thinking and processes; and iv) Analyzing, synthesizing and evaluating reasoning and procedures. Table 1 describes the assessment standards or learning progress of the Inquiring element in a mathematics curriculum (ACARA, 2015).

Level 1 (Year 1)	*Level 2 (Year 2)*	*Level 3 (Year 4)*	*Level 4 (Year 6)*	*Level 5 (Year 8)*	*Level 6 (Year 10)*
i_1. Pose questions					
	Identify a question of interest based on one categorical variable. Gather data relevant to the question	Identify questions or issues for categorical variables. Identify data sources and plan methods of data collection and recording	Pose questions and collect categorical or numerical data by observation or survey		Identify everyday questions and issues involving at least one numerical and at least one categorical variable, and collect data directly and from secondary sources
i_2. Identify and clarify information and ideas					
Compare and order the duration of events using the everyday language of time	Investigate number sequences, initially those increasing and decreasing by twos, threes, fives and ten from any starting point,	Use scaled instruments to measure and compare lengths, masses, capacities and temperatures	Investigate combinations of translations, reflections and rotations, with and without the use of digital technologies	Explore the practicalities and implications of obtaining data through sampling using a variety of investigative	Describe the results of two- and three-step chance experiments, both with and without replacements, assign probabilities to outcomes and

Level 1 (Year 1)	*Level 2 (Year 2)*	*Level 3 (Year 4)*	*Level 4 (Year 6)*	*Level 5 (Year 8)*	*Level 6 (Year 10)*
	then moving to other sequences			processes	determine probabilities of events. Investigate the concept of independence
i_3. ***Organize and process information***					
	Compare and order several shapes and objects based on length, area, volume and capacity using appropriate uniform informal units	Construct suitable data displays, with and without the use of digital technologies, from given or collected data. Include tables, column graphs and picture graphs where one picture can represent many data values	Investigate, with and without digital technologies, angles on a straight line, angles at a point and vertically opposite angles. Use results to find unknown angles	Describe events using language of 'at least', exclusive 'or' (A or B but not both), inclusive 'or' (A or B or both) and 'and'	Evaluate statistical reports in the media and other places by linking claims to displays, statistics and representative data

Source: ACARA, (2015).

TABLE 1: The Assessment Standards of the Element "Inquiring–identifying, Exploring and Organizing Information and Ideas" in the Australian Mathematics Curriculum.

The Ministry of Education and Training of Vietnam has issued a comprehensive general education curriculum towards capacity-based approach (Ministry of Education and Training, 2018), in which:

- New curriculum goal: "*creating a new generation of Vietnamese who are not only mentally and physically healthy but also able to unleash their own potential; who possess noble qualities, a general education, and core competences to use as a platform for future career options and lifelong learning*";
- A group of key student competences, including self-study, self-management, problem solving, communication, cooperation, literacy, numeracy, information technology, media…
- A concrete goal of the new curriculum outcome is considered a ***minimum*** requirement for graduation (in primary, lower secondary, and upper secondary school).

It's compulsory to demonstrate these elements clearly and as detailed as possible in the subject curriculum. To do that, we must first set up a key competences development model and construct an assessment standard for all subjects; then construct a new subject curriculum.

2. Research Methodology

Definition and structure of PSC

Using the definition of PSC from Deseco (2002), OECD (2004), OECD (2013), ACARA (2013), Griffin, P., Barry McGaw, B. và and Esther Care, E., (2012), and others, and by analyzing social requirements and the conditions of Vietnamese schools, it is proposed that the PSC represents the

individual ability to use cognitive processes, actions, attitudes, motives, and emotions effectively to solve situations in which the usual processes, procedures, and solutions are not available.
Based on the process of solving problem and on how information processes work when an individual participates in solving problems (Polya, G., 1957), PSC is structured according to four elements, each factor of which is expressed by some individual behavior when working independently or in a group (see Figure 1).

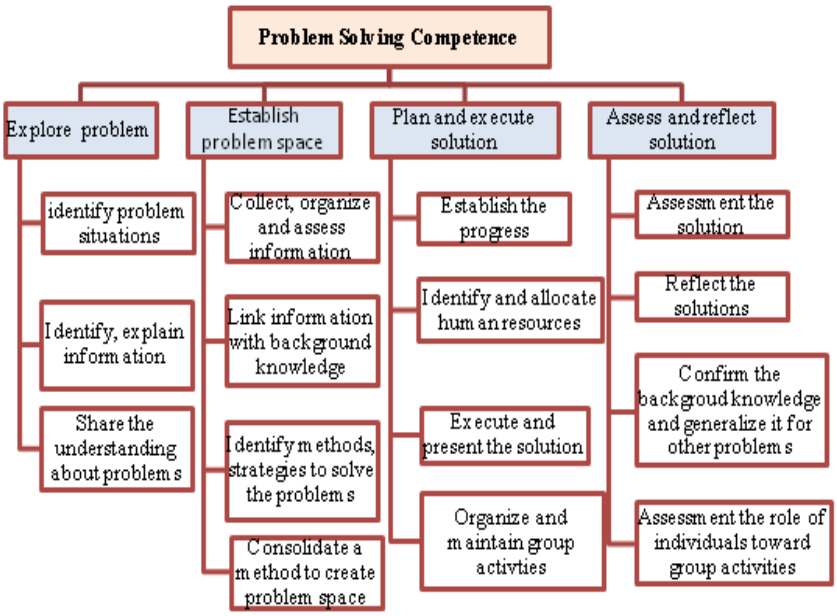


FIGURE 1. PSC Structure (Four element skills and 15 behavior indicators)

Theoretical Basic

The construction of assessment standards for the PSC is based on the following 4 theories:

(i) From Assessment to Policy Model of ATC21S

The ATC21S project is implemented with three loops and five steps can be seen in Fig. 2 (Patrick Griffin, Barry McGaw, Esther Care, p.11, 2012).

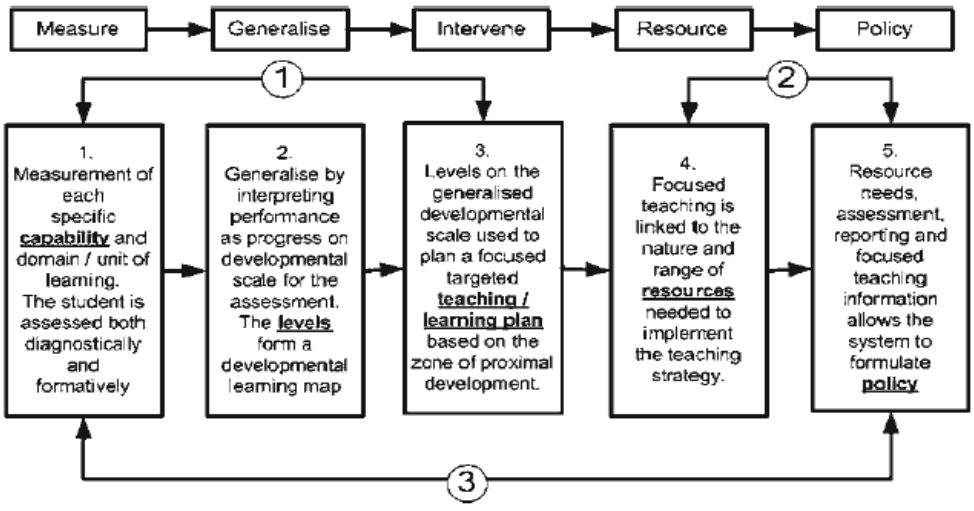


FIGURE 2. From Assessment to Policy by ATC21S

The first loop links measurement directly to intervention. The second loop links resources to policy. The third loop links measurement to policy. The five steps are assessment, generalization, intervention, resource allocation and policy development. When step two is omitted in the first loop, teachers tend to use an assessment to identify discrete points for teaching. When the second step (generalization) is included, intervention can be directly linked to a process of teaching to a construct in a developmental approach. The third loop links measurement to policy.

The common link is the progression through the five steps which connect learning and policy formation. Progression is achieved by assessing learning in a developmental framework, identifying the generalized level of development, linking resources to the level and intervention strategy, scaling up and formulating policy.

(ii) The Rasch Model and IRT

Georg Rasch proposed the idea of measuring learner competence (latent trait) based on two assumptions: For a question, the probability of a high-ability examinees' correct answer is higher than a low-ability examinees; and for an examinee, the probability of correctly answering difficult questions is lower than easy questions. He introduced the probability model to a person properly qualified θ to answer difficult questions b by the formula $p(\theta) = \frac{1}{1+e^{-(\theta-b)}}$. . This formula can help to locate the student capacity and the difficulty of the questions on the same scale, especially when the student capacity is equal to the difficulty question $(\theta = b)$ then the probability of doing the right thing is 0.5 (Rasch, G, 1980).

Item Response theory (IRT) models each individual's interaction with items to estimate the capacity and the difficulty of each item by maximum likelihood method on the difference between θ and b. Finally, assign each student a capacity value and a difficulty value for each item, and then put them on the same scale. Based on IRT, CONQUEST software has developed several models that measure learner's ability development, such as: Generalized Unidimensional Models are two forms Simple Logistic Model and Partial Credit Model; Multidimensional Item Response Models are two forms of multidimensional between-item tests; that is, each item is a one-dimensional indicator of latent variables, and multidimensional within-item tests; that is, each item is a multidimensional indicator of latent variables (Wu, M. and Adams, R. 2007).

(iii) Competence Developmental Progress by Robert Glaser (Griffin, P., 2014)

Robert Glaser developed a theoretical framework of criteria-referenced interpretation. The cornerstone of his framework is that knowledge acquisition can be conceptualized as a continuum, ranging from low to high proficiency. Points on the continuum are identified by behavioral criteria that indicate a particular level of proficiency has been reached. Thus the following sequence for conducting assessment is suggested:

(i) Identify construct
(ii) Articulate the construct in terms of observable evidence (criteria)
(iii) Validate the progression levels that are to be used for interpretation of the evidence;
(iv) Devise ways of assessment a person so that their performance can be placed at a level or stage on the progression of increasing competence; và
(v) Monitor progress by assessment at more than one point in time.

A crucial feature of Glaser's approach is that the student's level of competence is described in terms of the task performed or competence displayed. Each behavior criterion is considered within a close system of knowledge and skills, and fulfilling the criteria will describe the level of development of the human capacity to learn (Fig. 3).

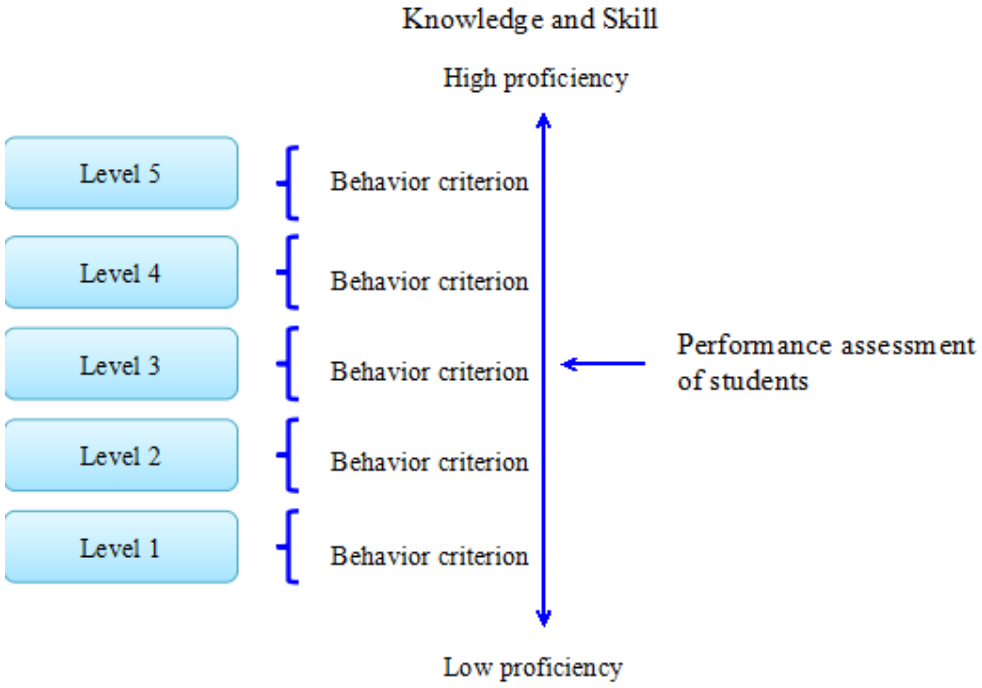


FIGURE 3. Chart of the Glaser's Competence Development Levels
Source: Griffin, P., (2014)

Hence, Glaser's theory helps simulate learning progress through competence development and explaining the study results under that level of development.

(iv) Construct Modeling Approach of BEAR

Construct Modeling Approach was suggested by BEAR (Mark Wilson, 2009), by which, the development of PSC assessment standards includes four stages:

(i) Draft hypothetical PSC assessment standards that include a developmental progress model and assessment standards;
(ii) Design PSC measurement tasks that include test blueprints, tasks, and item development;
(iii) Describe outcome spaces for the tasks; i.e., describe the outputs of each task or item and arrange the task or item level of implementation;
(iv) Adjust PSC assessment standards; i.e., measure and analyze the PSC of experimental students, encoder outputs, and capability maps. Then, adjust the development progress and PSC assessment standards.

At Stage 4, the measurement of PSC of student is also designed in a cross-sectional study model. Out of all the Vietnamese students, we chose 3 representative groups at the end of primary school level (grades 4 and 5), lower secondary school level (grades 8 and 9), and supper secondary school level (grades 11 and 12). The PSC was measured for all three groups of students at the same time as suitable for determining target levels of PSC development, based the reference of the hypothetical development progress and estimating the task difficulties that that the students encountered (see Figure 4). The sample of 900 students who participated in the experimental process was collected in two stages: i) Selection of a district in the area with average socio-economic conditions in Vinh Phuc, Dak Lak, and Nghe An; from this district, selection of two primary schools, two lower secondary schools, and two upper secondary schools in each district[1]; ii) Random selection of 50 students from each school according to the following breakdown: 20 from grade 4, 30 from grade 5, 20 from grade 8, 30 from grade 9, 20 from grade 11, and 30 in grade 12.

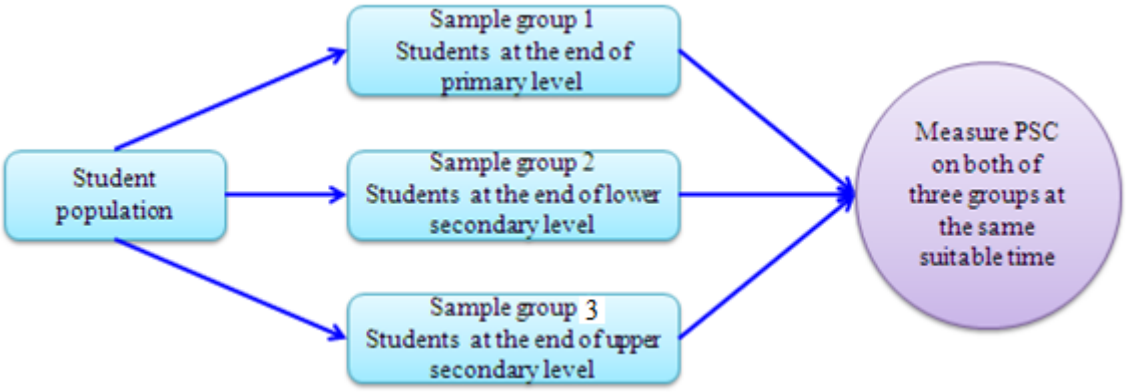


FIGURE 4. Cross-sectional study model for the PSC in Vietnam

It can be seen that the development of the PSC assessment standard is done in two steps of loop (1) of ATC21S, while loop (2) and loop (3) will be applied in the development of subjects. At step 1 'measure', IRT is used to assess learners' competencies; at step 2 'generalize', Glaser's theory is used to generalize competence developmental progress. The combination of both steps is based on the 4 stages of BEAR effectively

3. Results

In this section, we introduce a summary of the final results for each of the four stages shown in Figure 5.

i) Draft hypothetical PSC assessment standards

According to the PSC development progress from PISA 2003, PISA 2012, and ATC21S, the result of Vietnamese students (through large-scale assessment in 2011, 2014, PISA 2012, and PASEC 10) and the results of small surveys carried out among 1000 students in Experimental Schools of National Institute for Educational Sciences (VNIES), the PSC developmental progress with 5 levels are illustrated in Table 2.

Level	*Description*
Level 5 Propose the comprehensive solution and assessment	Make basic assumptions to find out optimal solution; propose possible solution for dynamic problems; present the relationship using symbols and formulas, evaluate the solutions.
Level 4 Generalize comprehensive strategies and solution	Study the methods and strategies to create a comprehensive solution that applies to a series of problem situations; possible to generalize the formulas, symbols and apply to comprehensive situations; possible to apply the solutions in unfamiliar circumstances.
Level 3 Execute the solution	Point out the process and principle for the solution; present, draw, tabulate, how to approach problems; utilize familiar processes and principles; start to extend the process for less familiar problems.
Level 2 Cognitive model, structure, process	Cognitive-one model or structure but unable to interpret its nature; able to draw, write, illustrate and give oral presentation about the solution for problems but not sufficient; start to change the available model and apply it to similar circumstances.
Level 1 Identify the problems	Able to analyze and identify the components of task but unable to carry out any actions.

TABLE 2: Hypothetical PSC developmental progress

Table 3 describes the draft of PSC Assessment Standards for students at primary school level and lower and upper secondary school levels in detail. Not only is it suitable according to the 5 levels mentioned previously, but it also clearly demonstrates the element skills and their behavior indicators (Figure 1).

Level	*Elementary schools*	*Lower secondary schools*	*Upper secondary schools*
5	Make assumptions for different solutions and predict possible results	Generalize the relationship by using symbols and formulas; compare the value of different solutions based on experiences	Assess the solution based on a clear criteria system, compare it with other solutions, identify new problems and propose flexible solutions
4	Recognize the methods and strategies to design representative components or mutual solutions for other similar or near similar problems	Apply different methods and strategies to design representative components or mutual solutions for a series of circumstances; confirm the value of selected solutions	Apply methods and strategies flexibly to design representative components and comprehensive definition, devise the generalized solutions for generalized problems; start to apply to less familiar problems
3	Implement the model, process, etc. for simple solutions (1 or 2 steps) in similar circumstances, may make clarification for each step	Explain the approaches, strategies, processes, etc.; execute complicated solutions (of more than 2 steps), start to recognize the value of the solution	Clarify and modify the mathematical model, structure, etc. in order to fit each circumstance, implement new and complicated solutions, determine whether these solutions are right or wrong
2	Identify the model, structure and related background knowledge which are not fully understood, create a tenuous link between background knowledge and information, and targets	Identify and clarify the model, structure and background knowledge that relate to the problems; possible to describe solutions for the relationships between information and background knowledge	Identify various models, structures and related and exchangeable background knowledge; describe the way (plan) or select the optimal solutions using logical explanation, analyze one's own ideas to find out the solutions
1	Identify available information for some static and simple problems; however unable to form the link between background knowledge and problems	Analyze and identify the information of static and complicated problems; understand to connect the problems with background knowledge (start to notice the importance of linking between each situation and the background knowledge)	Analyze and identify the component of static and complicated problems which are possible to influence indirectly which could possibly contain dynamic factors; understand to link the problems with background knowledge. (Aware of the linking between the situations and background knowledge)

TABLE 3: PSC Assessment Standards

ii) Design measurement tasks of the PSC

Although there are a number of possible tools that could be used to assess competence, a mathematical test is used to illustrate the method of measuring PSC in this research paper. There are two steps in the designing process: i) Design the tool (version 1) based on the draft assessment standard and the result from a small survey carried out on 150 students in Hai An Commune, Haiphong Province[2] (December, 2013) in order to assess the items; ii) Adjust the tool (version 2) and conduct the survey officially on 900 students in order to adjust the PSC assessment standards.

Test blueprints for three groups of students have two dimensions. One was about four elements and the other was about different levels of PSC development. There were behavior indicators in each matrix square (described in Table 3). There were 36 items for students at primary school, 36 items for lower secondary students, and 33 items for upper secondary students. There were common items for equating tests. There were nine items for primary and lower secondary school students' tests, and 14 tests for lower and upper secondary school students' tests. These items were distributed equally on a Logit scale. Table 4 shows the test matrix for primary school students. The other two tests were similar.

Level	*Explore problem*	*Establish problem space*	*Plan and execute solution*	*Assess and Reflect on solutions*
5	Use methods and strategies to learn about the information for familiar problems	Explain the links that relate to representative elements for less familiar problems	Propose common solutions for less familiar problems	
	Item 11	Item 28	Item 29	
4	Use methods and strategies to explore representative information for familiar problems	Initially know how to and strategies to set representative elements for less familiar problems	Analyze and present the solutions, then explain the execution of a 2-step solution on similar problems	Initially know how to and strategies to set representative elements, comprehensive solutions for similar problems
	Item 10	Item 36	Item 3, 12, 20	Item 33
3	Describe the model, structure, and related background knowledge, but not comprehensively understand them	Describe the model, structure, and related background knowledge, but not be able to comprehensively understand them, and create an informative link for simple solutions	Execute simple and familiar strategies, process, models, and solutions (2 steps)	Acknowledge other people's solutions and strategies
	Item 9, 25	Item 19, 23, 24, 35	Item 27, 6, 21, 8, 17, 4	Item 31
2	Describe the models, structures. and related background knowledge that are not fully understood	Make the simple link for elements of possible solutions	Execute an already known model that relates to simple solutions (1 step)	Acknowledge the solutions of other people via linking available information
	Item 26,	Item 13, 15, 16,	Item 14, 7,	Item 32
1	Identify key information for simple situations	Identify information; start to link information to background knowledge		
	Item 1, 18, 5, 34	Item 22, 2, 30		

TABLE 4: PSC estimating matrix test for primary school students (at grade 4 and 5)

Each item was designed to estimate one behavior in the test matrix. It is possible to design different items to solve different problems for one comprehensive task. Each task is designed to revolve around three axes: i) Real context/situation type (Personal, school/workplace, community, or mathematical

science); ii) mathematics contents (arithmetic and algebra, geometry and measuring quantities; statistics and probability); and iii) The level of measured competence (Figure 5).

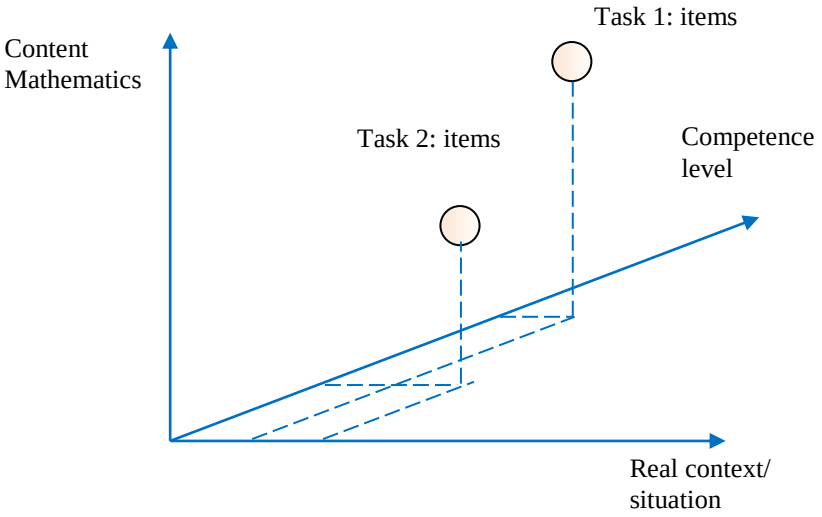


FIGURE 5. Model of PSC tasks/items design

Despite the same level of PSC development, the tasks for students at different school levels include: context/situation (personal life and school/workplace for students at primary school, school/workplace and community for students at lower secondary school, community and math science for students at upper secondary schools); characteristics of the problems (simple and static problems for students at primary schools, rather complicated and dynamic problems for students at lower secondary schools, complicated and dynamic problems for students at upper secondary schools).

The following table provides examples illustrating task modeling in the elementary school test.

ELECTRICITY CONSUMPTION

The price of electricity consumption in Vietnamese families is calculated based on the number of electricity units they have used. It's specified as follows:

First 100 units: 1,242 VND
Next 50 units: 1,369 VND
Next 50 units: 1,734 VND
Next 50 units: 1,877 VND

Item 10: ELECTRICITY CONSUMPTION

Last month, Hung's family consumed 150 units of electricity. How much does the family pay?

…….
…….
…….

Item 12: ELECTRICITY CONSUMPTION

In reality, the price above does not include taxes. Consumers have to pay 10% extra for taxes. If a family consumes 100 units per month, how much money do they have to pay in total?

…….
…….
…….

The test ELECTRICITY CONSUMPTION was developed using the context of community lives. The content is related to number calculation and the problems they need to measure are:

- Item 10: behavior 'Use methods and strategies to explore representative information for rather familiar problems', component 'Understanding problem'; competence level: 4;

- Item 12: behavior 'Analyze and present the solutions, then explain the execution of a 2-step solution on similar problems', component 'Planning and implementation of solutions'; competence level: 4;
Both of the items above measure high levels of PSC (level 4) because the given situation is less familiar with primary students. Students need to analyze to understand that the price of 1,242 VND per unit is for first 100 units, 1,369 VND per unit is for next 50 units, etc.

iii) Describe outcome spaces of the tasks

The performance scope of each task is all possible aspects to solve that task. Coding is conducted based on the way students can solve problems.
There are two types of items in the PSC tests:
- MCQ (Multiple Choice Question) is coded 1 for correct answer, and 0 for incorrect answers. Also, code 8 is for following the wrong instructions and 9 is for not attempting the item.
- Constructed-response item: the number of codes depends on the number of solutions and the number of criteria corresponding with behavior. The codes 8 and 9 are similar to MCQs.
Item 10 and 12 above are coded as follows:
- Item 10: code 0: incorrect; code 1 if answer has final results but the explanation is insufficient; code 2 if it has a full answer
- Item 12: code 0: incorrect; code 1 if answer has the calculation of the tax percentage but it is not complete; code 2 if it has the correct calculation of tax but the incorrect final result; code 3 if it has the full answer.

iv) Adjust PSC assessment standards

After being collected, encoded, entered and cleaned, data is analyzed and processed by the CONQUEST software according to IRT models. The difficulty levels of 82 items in three tests are put onto a common scale (through common items) by the concurrent calibration method. Specific parameters for each item are provided in the Annex.

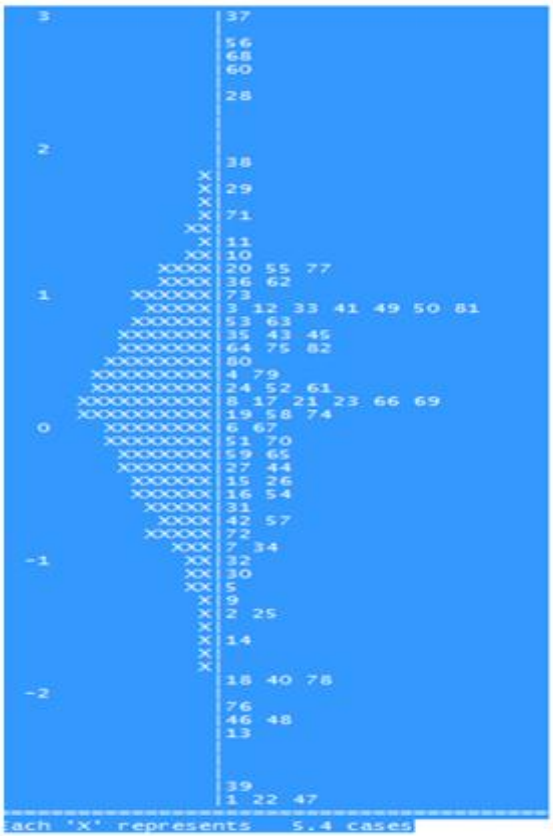


FIGURE 8. The balance between the difficulty level of 82 items and the competence of students

By using the model of polytomously scored items with the rating scale and partial credit models, we can see that the map in Figure 8 illustrates the balance between the difficulty level of 82 items and the competence of 900 students (with 0 as the average value). Students whose positions correspond horizontally with an item have a probability of 0.5 that they will answer the item correctly; when they get the positions higher or lower than an item, the probability of giving a right answer is respectively higher or lower than 0.5. We can be seen that the difficulty level distribution of the items is relatively suitable to the students' competence (spreading evenly over the scale), such that there are some fairly easy items (such as items 1, 22, 47, and 39), which most students are able to answer correctly, and some extremely difficult items such as items 37, 56, 60, 68, 28, which most of the students cannot answer correctly.

By using the Multidimensional Models, we can see that the map in Figure 9 shows the balance between the students' competence and the difficulty level of the four PSC elements on the same scale.

FIGURE 9. The balance map between the difficulty level of the components and students' competence

The first four blocks are the distribution of students' competence respectively in the following elements: 1) Explore problem, 2) Establish problem space, 3) Plan and execute solution, and 4) Assess and reflect solution (Figure 2). We see that the development of students' competence in the block Plan and execute solution is lower than in the other three blocks; specifically, that the students' competence in the Explore problem ranges from −2 to 3, and the sample mean is approximately 0.5. Students' competence in the Establish problem space ranges from −1.5 to 2.5, and the sample mean is approximately 0.5; students' competence in the Plan and execute solution ranges from −1.7 to 1.5, and the sample mean is approximately −0.5. Lastly, students' competence in the Assess and reflect solution ranges from −1.5 to 2, and the sample mean is approximately 0.5.

The assessment standards of PSC are adjusted through these four steps:
- Setting four cut-off scores to distinguish five different levels of PSC development using the Bookmark method (Jie Lin, 2006), based on the difficulty level of 82 items of the test. These cut-off scores are −1.70, −0.5, 0.57, and 1.52 (Figure 10).

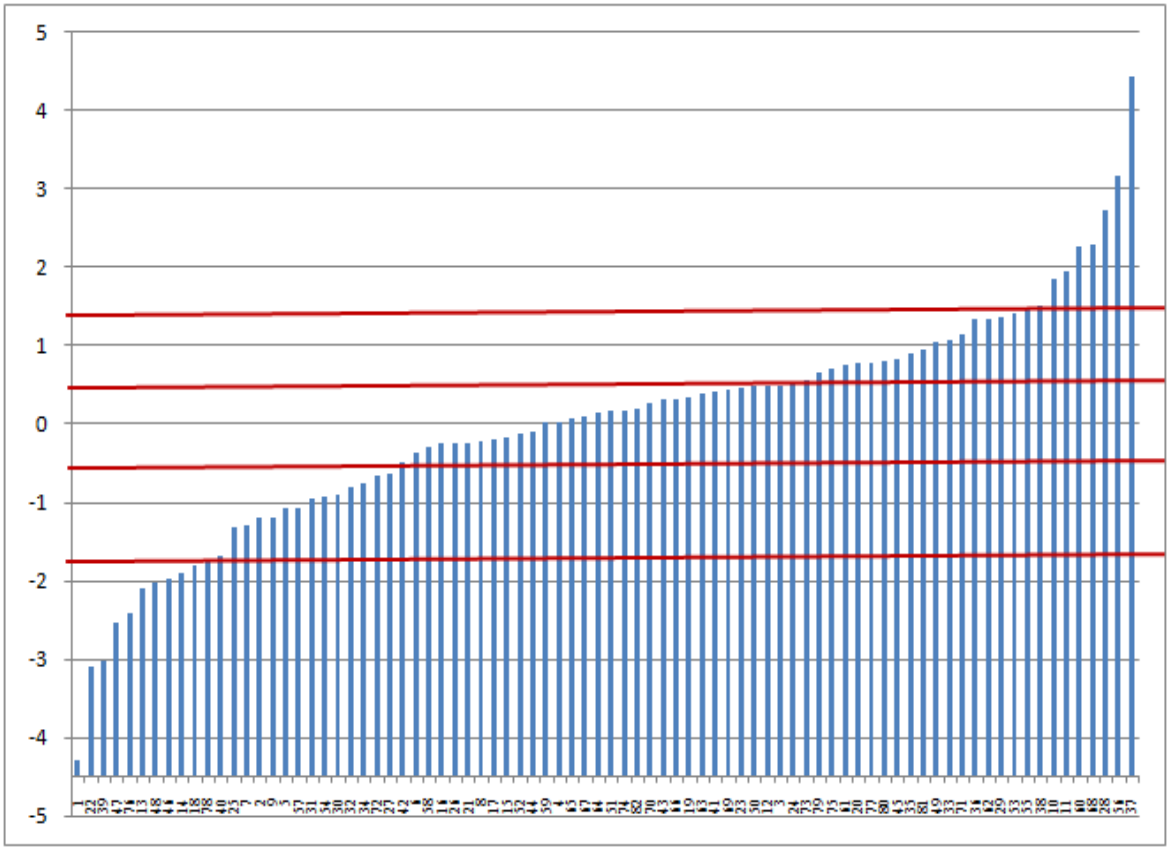


FIGURE 10. The cut-off scores on the scale of difficulty level of the items about PSC

- Readjustment of measurement skill for each item (has already identified in the test matrix) based on the difficulty level and the above cut-off scores;
- Generalization about the nature sign for each of the PSC development level through the content of Mathematics. Figure 11 demonstrates this adjusted PSC developing progress. It is illustrated using the double arrows with the implication that the development levels can be adjusted on both sides depending on whether the cognitive levels are lower than 1 or higher than 5. In addition, we also make a generalization about the nature signs for each development level corresponding to each element of PSC; and
- On the basis of five levels of the inclusive PSC development (based on Figure 8) and five levels of each element development (based on Figure 9), we adjust the final PSC assessment standard at the elementary and lower and upper secondary school levels. This process was also discussed in

consultation with many curriculum and education experts, together with the teachers from the school involved in the experiment.

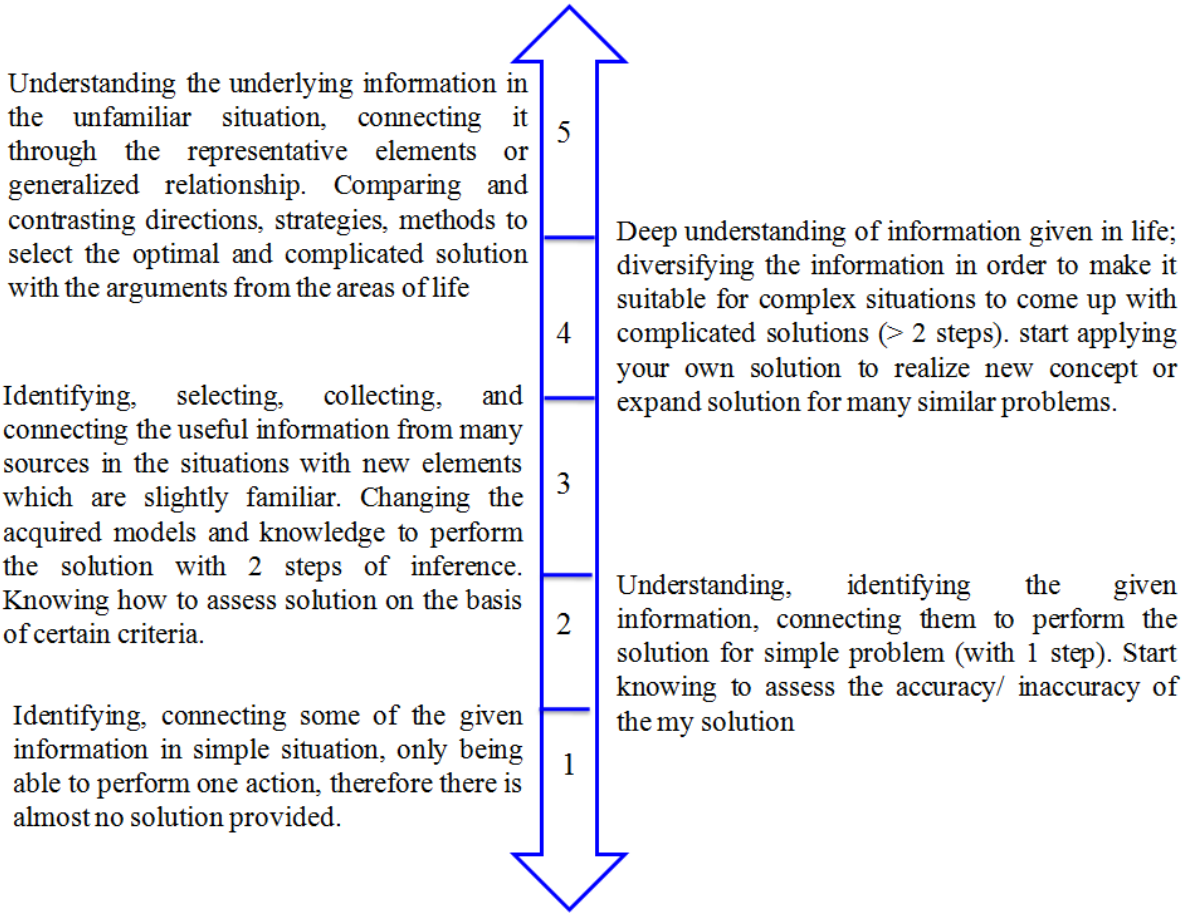


FIGURE 11. The adjusted PSC developing progress in math

Level	*The end of elementary level*	*The end of lower secondary level*	*The end of upper secondary level*
5	Indicate the information hidden in the explicit information. Start considering the connection between the information through the representative element. Compare, contrast, and use trial and error for the representative solution.	Analyze and explain the meaning of explicit and hidden information in solving generalized problems. Consider and explore the relationships of the representative element to propose open solutions for generalized problems.	Analyze and explain the explicit and hidden information in situations with dynamic elements. Diversify the relationship between this information and acquired knowledge to implement an open solution. Propose the direction for solution utilization for new problems.
4	Describe and explain information and initial state changes at the request of less familiar situation. Use acquired strategies and processes to implement the relatively	Have knowledge of initial and immediate information as well as the relationship between this information and acquired strategies, processes, knowledge, and life experience. Implement a relatively complicated solution	Understand the information (initial, intermediate, and target) in depth. Convert diverse information when linked with model, structure, and knowledge from many aspects of learning and life. Implement relatively

	complicated solution for less familiar problems.	for less familiar problems. Be able to expand the solution for many similar problems.	complicated solutions for less familiar problems with dynamic elements. Generalize about many other problems.
3	Start showing interest in the usefulness of initial information in an almost similar situation. Know method and strategy to connect information with learned knowledge, implement solution for static problem (2 steps). Have a sense of responsibility to recheck each step in the solution.	Collect and confirm the necessary information in a complex situation. Use relatively diversified methods and strategies to connect that information with learned knowledge and life experience to implement a solution for a less familiar problem (2 steps). Assess the accuracy/ inaccuracy of some solutions with relatively clear arguments.	Collect and confirm the necessary information in both the given and outside situations. Deploy diverse methods and strategies to connect acquired knowledge and life experience for implementation of solutions for practical problems (2, 3 steps). Provide assessment criteria for the solution in order to choose the optimal solution.
2	Describe some of the basic information and connect it with relevant knowledge in given situation. Take 1 or 2 actions, but these actions are not absolutely correct for the solution of simple problem.	Have deep knowledge of basic information and connect it with relevant models, structures and knowledge. Perform a simple solution (1 step). Start being conscious of reconsidering their own solution.	Convert different forms of given information flexibly; analyze the relationship of this information with learned models, structures, and knowledge. Perform the solution competently (1 step). Be conscious of reconsidering the accuracy/ inaccuracy of the solution.
1	Identify some of the information in a given situation; do not connect it. Also, no action performed to solve the problem.	Identify and connect some information in a given situation but do not connect it with the problem; perform 1 or 2 actions which are separate and unrelated to a simple situation.	Identify and connect some information in a given situation but do not connect it with the problem; perform 1 or 2 actions which are separate and unrelated to a simple situation.

TABLE 5: Detailed description of the final PSC assessment standard in math

Establishment of illustration form for PSC assessment standard in math:

We established the illustration forms for each development level in each block of the PSC that the assessment standards already identified from the participating students' test results in the standard experiment.
Table 6 demonstrates the final PSC assessment standard at the elementary school level.

Level	*Illustration of PSC assessment standards*
2	- Describe the basic information of a simple situation; - Be conscious of connecting it with relevant knowledge; - Perform 1 or 2 actions but these actions are not completely correct for the simple situation.

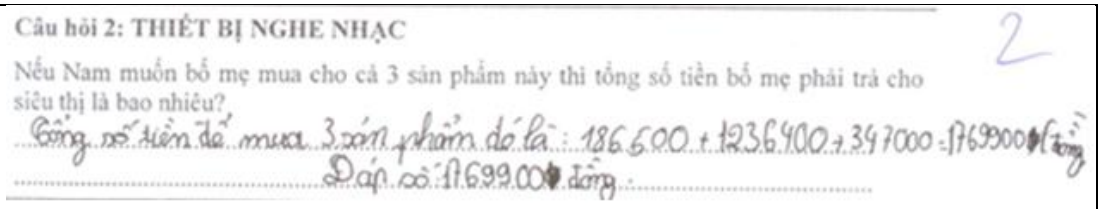
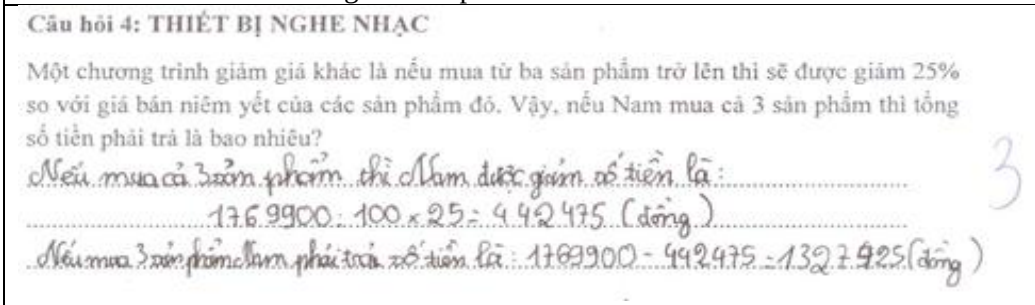
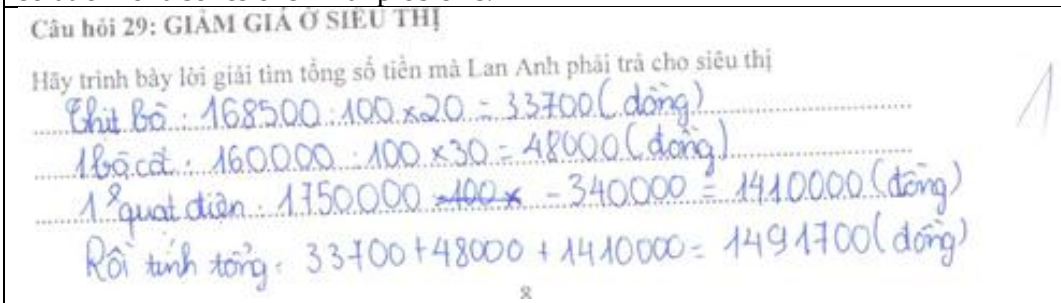
	 Câu hỏi 2: THIẾT BỊ NGHE NHẠC Nếu Nam muốn bố mẹ mua cho cả 3 sản phẩm này thì tổng số tiền bố mẹ phải trả cho siêu thị là bao nhiêu? Tổng số tiền để mua 3 sản phẩm đó là: 186 500 + 1236400 + 347000 = 1769900 (đồng) Đáp số: 1769900 đồng (Item 2: MUSIC PLAYERS If Nam wants to buy all three products, how much do his parents have to pay? The total cost of three products is: 186,500 + 1,236,400 + 347,000 = 1,769,900 VND Conclusion: 1,769,900 VND)
3	- Start displaying interest in useful initial and immediate information in an almost similar situation. - Know methods or strategies to connect information with learned knowledge; - Perform solutions for static problems (2 steps). - Be conscious of rechecking each step in the solution.
	 Câu hỏi 4: THIẾT BỊ NGHE NHẠC Một chương trình giảm giá khác là nếu mua từ ba sản phẩm trở lên thì sẽ được giảm 25% so với giá bán niêm yết của các sản phẩm đó. Vậy, nếu Nam mua cả 3 sản phẩm thì tổng số tiền phải trả là bao nhiêu? Nếu mua cả 3 sản phẩm thì Nam được giảm số tiền là: 1769900 : 100 x 25 = 442475 (đồng) Nếu mua 3 sản phẩm Nam phải trả số tiền là: 1769900 - 442475 = 1327425 (đồng) (Item 4: MUSIC PLAYERS Another sales promotion offers a 25% discount when buying three products or more. If Nam buys all three products, how much do his parents have to pay? If buying all three products, the amount deducted will be: 1,769,900: 100 x 25 = 442,475 VND If buying all three products, the amount actually paid will be: 1,769,900–442,475 = 1,327,425 VND)
5	- Point out the information hidden in the explicit and given information. - Start considering the connection between the information through representative elements. - Know how to compare, contrast, and use trial and error to provide the generalized solution for a series of similar problems.
	 Câu hỏi 29: GIẢM GIÁ Ở SIÊU THỊ Hãy trình bày lời giải tìm tổng số tiền mà Lan Anh phải trả cho siêu thị Thịt bò: 168500 : 100 x 20 = 33700 (đồng) 1 bộ cốc: 160000 : 100 x 30 = 48000 (đồng) 1 quạt điện: 1750000 - 100 x = 340000 = 1410000 (đồng) Rồi tính tổng: 33700 + 48000 + 1410000 = 1491700 (đồng) (Item 29: DISCOUNT IN SUPERMARKET Please give a detailed calculation of the total amount that Lan Anh has to pay the supermarket: Cost of beef: 168,500: 100 x 20 = 33,700 VND Cost of a set of cups: 160,000: 100 x 30 = 48,000 VND Cost of an electric fan: 1,750,000–340,000 = 1,410,000 VND Total amount: 33,700 + 48,000 + 1,410,000 = 1,491,700 VND)

TABLE 6: Illustration forms for PSC assessment standard at elementary school

4. Discussion and Conclusion

(i) The research results from a number of projects (PISA, ATC21S, and others) show a diverse picture of the PSC: the concept of a problem and its solution (is it static or dynamic; simple or complicated; decision-making or problem-solving); PS approach (problem-solving process or information processing when providing problem solutions); development methods for the PSC (individual analyzing problem, individual interacting with problem, or individuals working together to solve problem). Each approach results in the PSC being formed and developed under a specific structure.

This study applied the 'From Assessment to Policy' model of Assessment and Teaching 21th Century Skills (ATC21S) Project, 'Construct Modeling' of Berkeley Evaluation and Assessment Research (BEAR), 'Competence Developmental Progress' by Robert Glaser and Item Response Theory (IRT) to accomplish three main objectives. The first was to establish a 5-level developing progress for the PSC for Vietnamese students using four elements and 15 behaviors as the basic structure; the second was to develop the PSC assessment standard in math; and the final was to establish the illustration form for the PSC assessment standards.

(ii) Our research results and methodologies revealed some new points when compared to the experience of developing general education curriculum in Vietnam. These points are listed below:
- Most teachers do not have the bandwidth needed to focus on individual PSC development or to design and analyze the dynamic and real tasks required for studying and measuring PS interactions. The information and communication technology (ICT) environment in Vietnamese schools does not yet have the capacity to cooperate with PS according to ATC21S.
- The application of the above-mentioned models allowed us to refer to and compare a specific situation to the world research standards and achievements of outlining the PSC developing progress and PSC assessment standards. It also allowed us to establish a PSC development model suitable for Vietnamese students by adjusting the PSC developmental progress and PSC assessment standards.
- We propose the use of a cross-sectional assessment model that will lower the cost of standard establishment and still ensure the application of necessary scientific theory. IRT would allow learners' latent variables to be visualized more clearly and provide practical demonstration of the adjustment required for the initial PSC developmental progress.

(iii) The structure for a new general education curriculum has been identified. However, one of these challenges is developing the outcome standards and assessment standards for the curriculum. Therefore, we propose that:
- Developing assessment standards based on 'From Assessment to Policy' model of Assessment and Teaching 21th Century Skills (ATC21S) Project, 'Construct Modeling' of Berkeley Evaluation and Assessment Research (BEAR), 'Competence Developmental Progress' by Robert Glaser and Item Response Theory (IRT) would be an effective method of establishing a new direction for overcoming this challenge;
- Developing PSC assessment standards in math would demonstrate how to develop PSC assessment standards using content from different subjects in the new general education curriculum;
-
iv) Building the competence assessment standards through subjects as we propose has a number of disadvantages:
- Within the framework of this research project, the samples were selected in a way that facilitated the implementation. Therefore, the developing progress and the PSC assessment standards are displayed as illustrations of the method and process;
- It is essential to invest a certain amount of time and expenditure to establish the development progress and construct the assessment standards using a trial method.

(v) In conclusion, developing a competence-based curriculum always requires a competence development model and a competence assessment standard. It is possible to construct the PSC assessment standard using the following stages: i) Establish the PSC developmental progress and outline the assessment standard; ii) Design the PSC measurement tasks, iii) Describe the outcome

space for those tasks; iv) establish the proof map for students' PSC; and v) Adjust the PSC developing progress and competence assessment standards based on empirical proof.

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ANNEX

PSC item calibration at the elementary, lower and upper secondary school levels in math

Ordering item tests				*Difficulty items*		*Weighted fit*		
All	*Primary school*	*Secondary school*	*High school*	*Estimate*	*Error*	*MNSQ*	*CI*	*T*
37		1		4.45	0.13	1.08	(0.43, 1.57)	0.4
56		**29**	**7**	3.16	0.08	1.13	(0.76, 1.24)	1.1
28	28			2.73	0.08	1.00	(0.63, 1.37)	0.0
68			19	2.30	0.10	1.00	(0.56, 1.44)	0.1

Ordering item tests				*Difficulty items*		*Weighted fit*		
All	*Primary school*	*Secondary school*	*High school*	*Estimate*	*Error*	*MNSQ*	*CI*	*T*
60		**33**	**11**	2.27	0.08	1.01	(0.92, 1.08)	0.2
11	**11**	**7**		1.95	0.07	0.71	(0.81, 1.19)	−3.4
10	**10**	**6**		1.85	0.07	0.74	(0.82, 1.18)	−3.2
38		2		1.52	0.09	1.36	(0.65, 1.35)	1.9
55		**28**	**6**	1.49	0.06	0.84	(0.88, 1.12)	−2.7
53		**26**	**4**	1.41	0.07	1.13	(0.83, 1.17)	1.5
29	29			1.36	0.11	1.10	(0.05, 1.95)	0.4
62		**35**	**13**	1.35	0.06	0.93	(0.87, 1.13)	−1.1
36	36			1.35	0.08	1.05	(0.82, 1.18)	0.6
71			22	1.15	0.07	0.91	(0.73, 1.27)	−0.6
33	33			1.08	0.07	1.03	(0.87, 1.13)	0.4
49		22		1.04	0.07	0.96	(0.91, 1.09)	−0.9
81			32	0.96	0.22	1.21	(0.75, 1.25)	1.5
35	35			0.91	0.08	0.95	(0.84, 1.16)	−0.5
45		18		0.83	0.05	1.07	(0.85, 1.15)	1.0
80			31	0.80	0.36	0.84	(0.86, 1.14)	−2.3
77			28	0.78	0.09	1.06	(0.90, 1.10)	1.2
20	20			0.78	0.11	1.00	(0.55, 1.45)	0.1
61		**34**	**12**	0.76	0.08	1.15	(0.85, 1.15)	1.9
75			26	0.71	0.05	1.09	(0.82, 1.18)	1.0
79			30	0.67	0.07	1.03	(0.92, 1.08)	0.6
73			24	0.57	0.07	1.10	(0.86, 1.14)	1.4
24	24			0.54	0.06	1.09	(0.86, 1.14)	1.3
3	**3**	**16**		0.49	0.06	0.85	(0.87, 1.13)	−2.3
12	**12**	**8**		0.48	0.05	0.88	(0.83, 1.17)	−1.4
50		23	1	0.48	0.05	1.11	(0.91, 1.09)	2.2
23	23			0.47	0.06	0.94	(0.85, 1.15)	−0.7
69			20	0.45	0.07	1.19	(0.91, 1.09)	4.1
41		11		0.42	0.07	1.16	(0.82, 1.18)	1.7
63		**36**	**14**	0.39	0.05	1.24	(0.85, 1.15)	2.9
19	19			0.33	0.08	0.91	(0.88, 1.12)	−1.6
66			17	0.32	0.06	1.03	(0.85, 1.15)	0.5
43		13		0.31	0.07	0.98	(0.86, 1.14)	−0.3
70			21	0.27	0.34	1.02	(0.89, 1.11)	0.4
82			33	0.19	0.43	1.12	(0.71, 1.29)	0.8
74			25	0.18	0.07	0.95	(0.92, 1.08)	−1.4
51		**24**	**2**	0.18	0.04	1.10	(0.90, 1.10)	1.8
64			15	0.14	0.08	0.83	(0.84, 1.16)	−2.2
67			18	0.10	0.07	1.00	(0.90, 1.10)	0.1
65			16	0.08	0.07	1.14	(0.79, 1.21)	1.3
4	**4**	**17**		0.03	0.04	0.95	(0.88, 1.12)	−0.8
59		32	10	0.01	0.07	0.93	(0.93, 1.07)	−2.1

Ordering item tests				*Difficulty items*		*Weighted fit*		
All	*Primary school*	*Secondary school*	*High school*	*Estimate*	*Error*	*MNSQ*	*CI*	*T*
44		14		−0.10	0.06	0.95	(0.79, 1.21)	−0.4
52		25	3	−0.12	0.03	0.97	(0.89, 1.11)	−0.5
15	15			−0.16	0.07	0.89	(0.92, 1.08)	−2.7
17	17			−0.21	0.06	0.96	(0.88, 1.12)	−0.6
8	**8**	**5**		−0.23	0.05	1.08	(0.92, 1.08)	1.9
21	21			−0.24	0.06	0.95	(0.83, 1.17)	−0.5
26	26			−0.25	0.10	0.95	(0.90, 1.10)	−1.1
16	16			−0.26	0.07	0.95	(0.92, 1.08)	−1.2
58		**31**	**9**	−0.30	0.04	0.99	(0.89, 1.11)	−0.1
6	**6**	**3**		−0.36	0.07	1.13	(0.95, 1.05)	5.1
42		12		−0.50	0.08	1.02	(0.86, 1.14)	0.3
27	27			−0.63	0.09	0.89	(0.93, 1.07)	−3.1
72			23	−0.65	0.07	0.91	(0.86, 1.14)	−1.3
34	34			−0.76	0.10	1.05	(0.89, 1.11)	0.9
32	32			−0.81	0.07	0.92	(0.90, 1.10)	−1.5
30	30			−0.91	0.07	0.98	(0.89, 1.11)	−0.3
54		**27**	**5**	−0.92	0.08	0.99	(0.92, 1.08)	−0.3
31	31			−0.95	0.09	0.91	(0.92, 1.08)	−2.3
57		**30**	**8**	−1.07	0.08	0.94	(0.92, 1.08)	−1.5
5	5			−1.08	0.10	1.03	(0.87, 1.13)	0.4
9	9			−1.18	0.10	0.93	(0.86, 1.14)	−1.0
2	**2**	**15**		−1.20	0.06	1.08	(0.84, 1.16)	1.0
7	**7**	**3**		−1.28	0.08	0.90	(0.92, 1.08)	−2.6
25	25			−1.32	0.10	0.98	(0.84, 1.16)	−0.2
40		10		−1.70	0.08	0.99	(0.72, 1.28)	0.0
78			29	−1.74	0.07	1.01	(0.81, 1.19)	0.1
18	18			−1.80	0.11	0.98	(0.79, 1.21)	−0.2
14	14			−1.91	0.10	0.93	(0.85, 1.15)	−0.9
46		19		−1.98	0.08	1.02	(0.68, 1.32)	0.1
48		21		−2.02	0.07	1.00	(0.70, 1.30)	0.0
13	13			−2.09	0.08	1.00	(0.76, 1.24)	0.0
76			27	−2.42	0.11	0.97	(0.69, 1.31)	−0.2
47		20		−2.54	0.08	1.01	(0.57, 1.43)	0.1
39		9		−3.02	0.12	0.97	(0.58, 1.42)	−0.1
22	22			−3.09	0.08	0.99	(0.57, 1.43)	0.0
1	1			−4.29	0.13	1.00	(0.31, 1.69)	0.1