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APPLYING FORMATIVE ASSESSMENT STRATEGIES IN TEACHING PROBABILITY IN GRADE 10 AT HIGH SCHOOLS

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Abstract. Educational reforms involving assessment have become an important factor in attempts to improve achievements in schools. Formative assessment is the collection of information about student understanding and progress during the learning process. This information can be used as feedback to help students learn more effectively. This article aims to explain the definition of formative assessment and propose some formative assessment strategies that can be applied in teaching probability in grade 10 at high schools.

Keywords: assessment in education, classroom assessment, formative assessment, formative assessment strategies, high school mathematics education, teaching probability.

1. Introduction

Assessment is the means by which we determine what students know and can do. It tells teachers, students, parents, and policymakers something about what students have learned such as the mathematical terms they recognize and can use, the procedures they can carry out, the kind of mathematical thinking they do, the concepts they understand, and the problems they can formulate and solve [1]. In general, there are two types of following assessment such as summative assessment and formative assessment. Summative assessments are usually formal assessments that are given at the end of a unit of study or as a culminating test for the year. These assessments are often paper-and-pencil type tests with multiple choice, matching, free response, essay, or open-ended questions. They are specifically graded, and although they can be used to drive future instruction, they are often used for the purpose of evaluating a student's overall progress [2]. Formative assessments can be formal or informal. They are primarily used to provide the teacher with feedback on student understanding and progress during a unit of study. Based on the results, the teacher decides if instruction needs to be slowed or quickened to best meet the students' needs. This type of assessment should not be viewed as extra work [2]. "Formative assessment is part of good teaching" and should provide seamlessness between instruction and assessment [3]. Researchers have shown that formative assessments can improve the achievements of students [4-6].

Probability is an important topic at high school because it has various applications in real life and other disciplines. Although recognized the crucial role of this topic, the teaching of probability is not considered reasonable. Students still always have difficulties in learning this topic and do not know how to improve their understanding of probabilities.

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There have been studies on formative assessment [3, 4, 6-8] and formative assessment in teaching mathematics [2], but there are no studies on formative assessment in teaching probability at high schools. Based on the above-mentioned reasons, this paper aims to research formative assessment strategies that can be used in teaching mathematics at the high school level and apply them in teaching probability in grade 10 at high schools.

2. Content

2.1. Definitions of formative assessments

A variety of definitions of the term *formative assessment* have been proposed over the years. Black and Wiliam [4] defined formative assessment "as encompassing all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged" (p. 7). According to Black and Wiliam, the essence of formative assessment is the idea that evidence of student achievement is elicited, is interpreted, and leads to action that results in better learning than would have been the case in the absence of such evidence [9].

Cowie and Bell [10] made a restriction on the definition by adding a condition that formative assessment must be conducted and acted upon while learning was taking place. These authors defined formative assessment as "the process used by teachers and students to recognize and respond to student learning in order to enhance that learning, during the learning" (p. 32).

The requirement that the assessment is conducted during learning was also supported by Shepard, Hammerness, Darling-Hammond, and Rust [11] in their definition of formative assessment as "assessment carried out during the instructional process to improve teaching or learning" (p. 275).

Kahl [12] also emphasized the principle the assessment should take place during instruction when he wrote "A formative assessment is a tool that teachers use to measure student grasp of specific topics and skills they are teaching. It's a 'midstream' tool to identify specific student misconceptions and mistakes while the material is being taught" (p.11).

Although have different definitions, all the above-mentioned authors shared the opinion that formative assessment provides information to be used as feedback to teachers or students to help students learn more effectively. To emphasize this aim, we use the definition of the Organization for Economic Cooperation and Development (OECD) as follows: *"Formative assessment refers to frequent, interactive assessments of students' progress and understanding to identify learning needs and adjust teaching appropriately"* (cited in [7], p.21).

2.2. Goals of formative assessments

According to Wiliam & Thompson [13], formative assessments help to answer the underlying questions: "What is working?", "What needs to be improved?", and "How can it be improved?". More specifically, the goals of formative assessments can be listed as follow:

- *Provide feedback that moves learners forward:* formative assessments inform students (and teachers) about where they are in relation to the learning goal. Students can know clearly what they have achieved and what they still have not reached. Then they together with their teacher can make a plan to improve their learning.

- *Activate students as the owners of their own learning:* formative assessments specify the learning intentions in terms of clear goals. Because of that, students understand the expectation and criteria for success. This help students to consider their own learning style, their strength, their weakness, therefore thinking of how they learn and what they should do to achieve the learning goals.

- *Adjusting teaching to take account of the results of assessment:* formative assessments provide teachers with feedback on student understanding and progress during the learning process. Based on the results, the teacher identifies adjustments in content and teaching methods to best meet the students' needs.

2.3. Formative assessment strategies

Based on Angelo & Cross [14] and Mink [2], we propose the formative assessment strategies which can be applied in teaching mathematics at the high school level as follow:

**** Observation***

Observation can be made at many different points during the instruction of a concept. It can help to know a true picture of the progression of student understanding of a concept. Observation can be used when assessing behaviors such as concentration, attitude toward problem-solving, accuracy using manipulatives, and ability to work with others on mathematical tasks [2].

Tools used for observations can be checklists, rubrics, notes, or video recording. When observational data is compiled, the data can be used to guide future instruction.

**** Interviews***

Interviews are an important strategy to use when assessing students' mathematical thinking. By engaging in dialog with students, you can ask them what they know and then respond with follow-up questions to more deeply understand their thinking. Interviewing also allows you to get an idea of students' ability to make connections and communicate their thinking process [3].

Additionally, interviews can help the teacher identify exact student needs and misconceptions.

Instruction can then be modified to reteach those precise areas in which the need exists. For above-level students, interviews can be a method of discourse where they can explain to their heightened understanding of the concepts being discussed [2].

Tools used for interviews can be questions, a checklist, rubrics.

**** Background knowledge probes***

Background knowledge probes are short, simple questionnaires prepared by teachers for use at the beginning of a course, at the start of a new unit or lesson, or before introducing an important new topic. A given background knowledge probe may require students to write short answers, to circle the correct responses to multiple-choice questions, or both. Background knowledge probes are meant to help teachers determine the most effective starting point for a given lesson and the most appropriate level at which to begin instruction. For students, the background knowledge probes focus attention on the most important material to be studied, providing both a preview of what is to come and a review of what they already know about that topic [14].

**** Memory matrix***

The memory matrix is simply a two-dimensional diagram, a rectangle divided into rows and columns used to organize information and illustrate relationships. In a memory matrix, the row, and column headings are given, but the cells, the boxes within are left empty. When the students fill in the blank cells of the memory matrix, they provide feedback that can be quickly scanned and easily analyzed. The memory matrix assesses students' recall of important course content and their skill at quickly organizing that information into categories provided by the teacher. By using this strategy, teachers can quickly see not only whether their students have memorized the basic information but also how well they have organized that information in their memories [14].

**** Application card***

After students have heard, read, or learnt about an important principle, generalization, theory, or procedure, the teacher hands out a card and asks them to write down at least one real-world application for what they have just learned. That is the application card strategy. Application card helps the teacher know how well students understand the possible applications of what they have learnt. This strategy prompts students to think about possible applications and, as a consequence, to connect newly learned concepts with prior knowledge. As they respond to the technique, students also see more clearly the possible relevance of what they are learning [14].

**** Problem recognition tasks***

Problem recognition tasks present students with a few examples of common problem types. The students' task is to recognize and identify the particular type of problem each example represents. In many fields, students learn a variety of problem-solving methods, but they often have difficulties determining which kinds of problems are best solved by which methods. Problem recognition tasks help teachers to assess how well students can recognize various problem types, the first step in matching problem type to solution method. As students work through this strategy, they practice thinking generally about problems they often view as individual, isolated exemplars [14].

**** Documented problem solution***

The documented problem-solution strategy prompts students to keep track of the steps they take in solving a problem to "show and tell" how they worked it out. By analyzing these detailed protocols in which each solution step is briefly explained in writing - teachers can gain valuable information on their students' problem-solving skills. Documented problem-solution strategy has two main aims: to assess how students solve problems and to assess how well students understand and can describe their problem-solving methods. Therefore, the primary emphasis of the strategy is on documenting the specific steps that students take in attempting to solve problems, rather than on whether the answers are correct or not [14].

**** Graphic organizers***

Graphic organizers make powerful tools that are easy to implement and allow you to thoroughly examine student thinking and learning. Graphic organizers also let you assess ongoing learning that is conceptual, hierarchical, cyclical, and sequential [15].

After teaching a concept, students can provide a "visual representation of knowledge" and understanding through a graphic organizer that fits the concept [16]. Some graphic organizers that work well with mathematics instruction are flow charts, Venn diagrams, circle maps, concept web, or double bubble maps [17].

Once students have visually represented their understanding by completing a graphic organizer, it is important to provide them with feedback. This process will help students correct misconceptions, deepen their understanding of the concept, and make connections to prior knowledge [2].

**** Self-evaluation***

Using self-evaluation is an efficient way to understand how students view their achievements. It also allows them to assess their work habits, attitudes, and thinking process. In addition, the self-evaluation strategy helps students to collaborate about their understanding and strengthen their abilities. Teachers should discuss the criteria for evaluation openly, provide samples of completed evaluations for students to view, using constructive feedback when informally discussing students' performance, allow students to complete private self-evaluations

before completing those that are collected for teacher viewing [2]. Tools used for self-evaluation can be rubrics, checklists, and rating scales.

2.4. Applying formative assessment strategies in teaching probabilities in grade 10 at high schools

2.4.1. The content of probability in grade 10 at high schools

According to the Mathematics Curriculum 2018, the main content of probability in grade 10 are the following:

-The concepts of probability, including some concepts related to classical probability such as a random trial, sample space, event, the complement of an event, classical definition of probability, small principle of probability.

- Rules to calculate probability, including calculating probabilities of events in simple - problems by using combinatorics, calculating probabilities in some repeated experiments by using tree diagrams, and calculating the probability of the complement of an event.

Based on the achievement goals of the topic "Probability" in grade 10 presented in the mathematics curriculum 2018, we propose the assessment strategies as described in Table 1.

Table 1. Assessment strategies in teaching probability for grade 10 students

Topics	Sub-topics	Achievement goals	Assessment strategies
The concepts of probability	Some concepts related to classical probability	- Can identify some concepts related to classical probability such as a random trial, sample space, event, the complement of an event, the classical definition of probability, the small principle of probability. - Can describe sample spaces and events in simple experiments (throw a coin, roll a die, etc.).	- Background knowledge probe, memory matrix, interview, self-evaluation.
Rules to calculate the probability	Practice to calculate probability in simple cases	- Can calculate the probabilities of events in simple problems by using combinatorics. - Can calculate probabilities in some repeated experiments by using tree diagrams (Example: Roll a die two times, calculate the probability that the sum of the two rolls is 7).	- Problem recognition task, documented problem solution, application card, graphic organizer, observation.
	Rules to calculate the probability	- Can describe fundamental properties of probability. - Can calculate the probability of the complement of an event.	- Background knowledge probe, memory matrix.

2.4.2. Examples of the proposed assessment strategies

To make clear how to apply the proposed assessment strategies in teaching probability in grade 10 at high schools, we show the illustrated examples as follow:

Example 1. *Background knowledge probe*

- Assessment aims: Students can repeat the definition of sample space, event, the classical definition of probability. Students can describe the fundamental properties of probability.

- Before starting to teach students about calculating probability, the teacher gives students the following worksheet to assess their background knowledge of some concepts related to classical probability:

Worksheet

Please fill in the blanks the appropriate words:

1) A… is the set of all possible outcomes (Answer: sample space).

2) An event is a single……. or …… of outcomes (Answer: outcome/group).

3) You can determine the classical probability of an event if you know all the possible outcomes and they are…….

$$P(event) = \frac{number\ of\ \ldots}{total\ number\ of\ possible\ outcomes}$$

(Answer: equally likely/favorable outcomes).

4) The probability that something will occur is a value from… to…, which describes its likelihood. You can write probability as…, such as ½, or as…, such as 50%. (Answer: 0/1/ratio/percent).

5) If an event cannot occur, then its probability is…, and when an event is certain to occur, then its probability is… (Answer: 0/1).

6) The closer the probability is to 0, the less likely it is that the event will…The closer the probability is to…, the more likely that the event will occur (answer: occur/1).

Example2. *Memory matrix*

- Assessment aim: Students can use the language of the small principle of probability.

- After teaching about the small principle of probability, a teacher gives students the following worksheet to assess how they understand the principle.

Worksheet

Huy is going to select a card from the group of cards including one card labeled 1, one card labeled 2, two cards labeled 3, and 6 cards labeled 5, please complete Table 2.

Table 2. Memory matrix to assess how students use the language of the small principle of probability

Likelihood / Event	Impossible	Unlikely	Likely	Certain
a) Huy will select a card labeled 5.				
b) Huy will select a card labeled 1.				
c) Huy will select a card with a number less than 6.				
d) Huy will select a card labeled 4.				
e) Huy will select a card with an odd number.				
f) Huy will select a card labeled 2.				
g) Huy will select a card labeled 3.				

Example 3. *Interview*

- Assessment aims: Students can describe sample spaces and events in simple experiments. Students can calculate probabilities in simple cases.

- A teacher gives students the following problem: Oanh is going to spin the pointer on the right. a) Describe the sample space of this experiment; b) Find the probability that the pointer landing on letter A. The questions for the interview are the following:

1) How do you describe the sample space of this experiment?

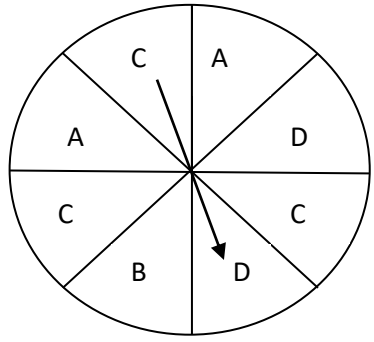
2) To find the probability that the pointer landing on letter A, what do you need to do first?

3) How do you describe the favorable outcomes of event A: the pointer landing on letter A?

4) What should you do next?

5) What is the next step?

6) How can you conclude about the probability?



The interview checklist can be illustrated in Table 3.

Table 3. Interview checklist

Criterias	Yes	No
Students can describe the sample space as S = {A, D, C, D, B, C, A, C}.		
Students can suppose that event A is the event that the pointer landing on letter A.		
Students can count exactly all the possible outcomes, which is 8.		
Students can count exactly the number of favorable outcomes for the event A, which is 2.		
Students can conclude exactly the probability that the pointer landing on letter A is P(A) = 2/8 =1/4.		

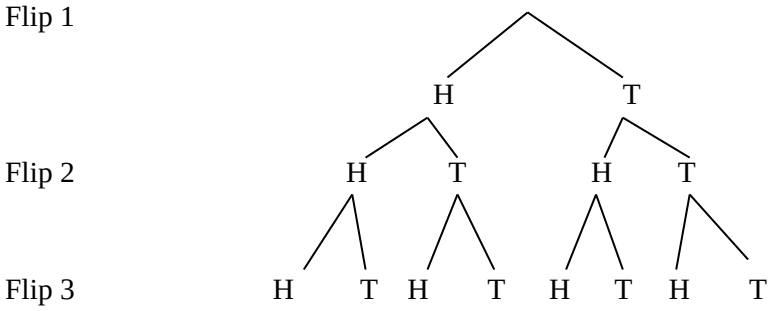
Example 4. *Observation*

- Assessment aim: Students can calculate probabilities in some repeated experiments by using tree diagrams.

- Teacher asks students to write down the solution for the following problem and observes what they do.

Problem: What is the probability that a coin flipped 3 times will land heads up exactly 2 times? Please solve this problem by using tree diagrams.

Students are expected to establish the following tree diagram (H = Heads, T = Tails):



Outcomes HHH-HHT-HTH-HTT-THH-THT-TTH-TTT

The observation checklist can be described as follow:

Table 4. Observation checklist

Criteria	Yes	No
Students can establish exactly the part of the tree diagram for flip 1.		
Students can establish exactly the next part of the tree diagram for flip 2.		
Students can establish exactly the next part of the tree diagram for flip 3.		
Based on the tree diagram student can conclude that the probability that a coin flipped 3 times will land heads up exactly 2 times is 3/8, or 37,5%.		

Example 5. Problem recognition task

- Assessment aim: Students know how to calculate the probabilities of events in simple problems.

- Teacher asks students to match each problem in the left column with the appropriate type of problem in the right column of Table 5.

Table 5. Problem recognition task

Problem	Type of problem
1) A box contains 4 green marbles, 3 red marbles, and 2 yellow marbles. Mai chooses randomly 2 marbles. What is the probability that Mai chooses 2 marbles of the same color?	a) Calculate probability by using a tree diagram.
2) What is the probability that at least 2 fair coins land heads up when 3 are flipped?	
3) Suppose you have a bag of 20 marbles, and 3 of them are red. Suppose a second bag has 50 marbles, and 7 of them are red. From which bag are you more likely to pick a red marble?	b) Apply directly the formula of classical probability. c) Calculate probability using combinatorics.

The expected answer is 1) and c), 2) and a), 3) and b).

Example 6. *Documented problem solution*

- Assessment aim: Students can calculate the probabilities of events in simple problems by using combinatorics.

- A teacher asks students to present steps to solve the following problem:

Problem: From a group of students including 10 boys and 8 girls, 3 students are to be selected at random to form a committee. What is the probability that at least 2 boys are selected?

In this strategy, students do not need to calculate exactly the probability. It is important that they can present the steps to solve the problem. The expected answer is following:

Step 1: Suppose that event A: exactly two boys and 1 girl selected; event B: exactly 3 boys selected.

Step 2: Use combinatorics to calculate P(A) = $\frac{C_{10}^{2}\ C_{8}^{1}}{C_{18}^{3}}$; P(B) = $\frac{C_{10}^{3}}{C_{18}^{3}}$.

Step 3: The probability that at least 2 boys are selected is P(A) + P(B).

Example 7. *Memory matrix*

- Assessment aims: Students can identify the complement of an event. Students can calculate the probability of the complement of an event.

- Teacher gives the following problem:

For the experiment of rolling two dice, please complete Table 6.

Table 6. Memory matrix to assess students' understanding of "the complement of an event and its probability"

Event A	**Favorable outcomes for event A**	**P(A)**	$\boldsymbol{Event\ \overline{A}}$	$\boldsymbol{P(\overline{A})}$
Both dice show the same number	{(1,1),(2,2),(3,3),(4,4),(5,5),(6,6)}	1/6	Both dice show different numbers.	5/6
The product of the numbers showing on the two dice is less than 10				
	{(1,6),(2,5),(3,4),(4,3),(5,2),(6,1)}			
			The sum of the numbers showing on the two dice is different from 6.	

Example 8. *Application card*

- Assessment aims: Students know the applications of probability in real life. Students can calculate probabilities in simple cases.

- At the end of the chapter, a teacher gives students the following application card:

Application card

Question 1: Present one application of probability in real life.

Question 2: A store is giving every customer who enters the store a scratch-off card labeled with numbers from 1 to 10. It is equally likely that any of the numbers from 1 to 10 will be labeled on a given card. If the card is an odd number, the customer gets a 10% discount on a purchase. If the card is an even number greater than 7, the customer gets a 30% discount. Otherwise, the discount is 20%.

a) What is the probability for each discount?

b) The store manager gives out 100 scratch-off cards. Which discount will the greatest number of customers likely receive? Explain.

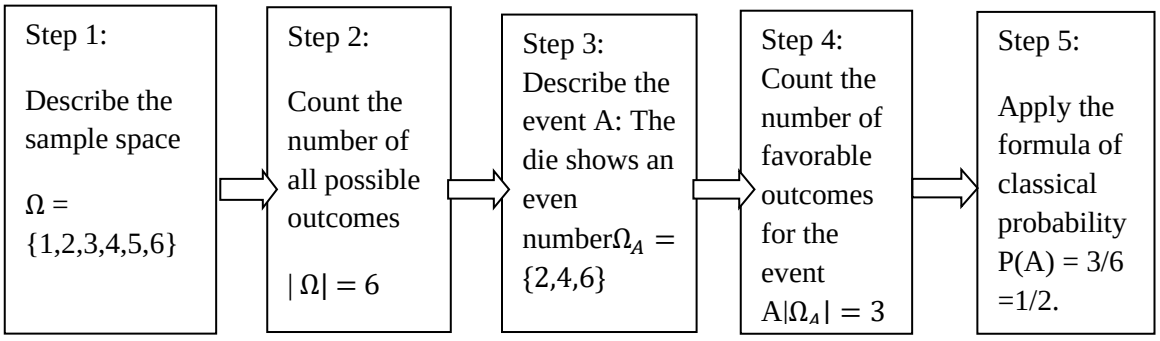
Example 9. *Graphic organizer*

- Assessment aim: Students know the steps to find the classical probability of an event.

- Teacher uses the following flow chart to assess students' understanding of the procedure to find the classical probability of an event.

Worksheet

Direction: Write the steps in the boxes below to explain the procedure to find the classical probability of an event. In this case, the experiment is rolling a die, and event A is "the die shows an even number".



Example 10. *Self-evaluation*

- Assessment aim: Students themselves can know what they have achieved after learning the topic.

- After learning the topic, the teacher gives the following self-evaluation checklist to understand how students view their achievements:

Instruction: Read the following information, tick on the content that you can do.

☐ I can repeat the definition of sample space.

☐ I can repeat the definition of the event.

☐ I can describe sample spaces and events in simple experiments.

☐ I can describe the complement of an event.

☐ I know how to calculate the probability of the complement of an event.

☐I know how to use the formula of classical probability to calculate the probability of an event.

☐ I know how to use tree diagrams to calculate probability.

3. Conclusions

There is no doubt that assessment is a necessary part of education today. Formative assessment provides the teacher with feedback on student understanding and progress and helps the students learn more effectively. This article has summarized researches on formative assessment to make clear its definition, its goals, and its strategies. Based on the literature review, the article proposed the formative assessment strategies that can be applied in teaching mathematics at the high school level. For the topic "probability" in grade 10 at high schools, the article chose appropriate assessment strategies for each achievement goal of this topic. Then specific assessment tools and assessment content for each strategy are identified. These assessment tools and content can be considered as illustrating examples of applying the proposed formative assessment strategies in teaching probability for grade 10 high school students.

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