FLIPPED

EMBEDDING QUESTIONS IN VIDEOS

LEARNING:

Use math videos and different types of inquiries to increase students' intellectual engagement.

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Ashley D. Wilson

More teachers are trying out the flipped classroom model in which content is delivered outside of class time, typically through online videos and "homework," and follow-up activities are done in class. This model frees up more class time for inquiry and discussion. Survey results show that the percentage of teachers who indicated that they had flipped a lesson during the school year increased from 48 percent in 2012 to 78 percent in 2014 (cited in Yarbro et al. 2014).

Articles on flipped instruction suggest such benefits as (1) freeing up class time for meaningful

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activities and formative assessment; (2) increasing student engagement, motivation, and content knowledge; and (3) offering slower learners the opportunity to pause, rewind, and review segments of videos (Bergmann =and Sams 2012; Moore, Gillett, and Steele 2014; Tucker 2012). The flipped model gains traction because of the availability of online videos such as those produced by Khan Academy and LearnZillion. However, the flipped model is ineffective if it is implemented as "a high-tech version of an antiquated instructional method: the lecture" (Ash 2012).

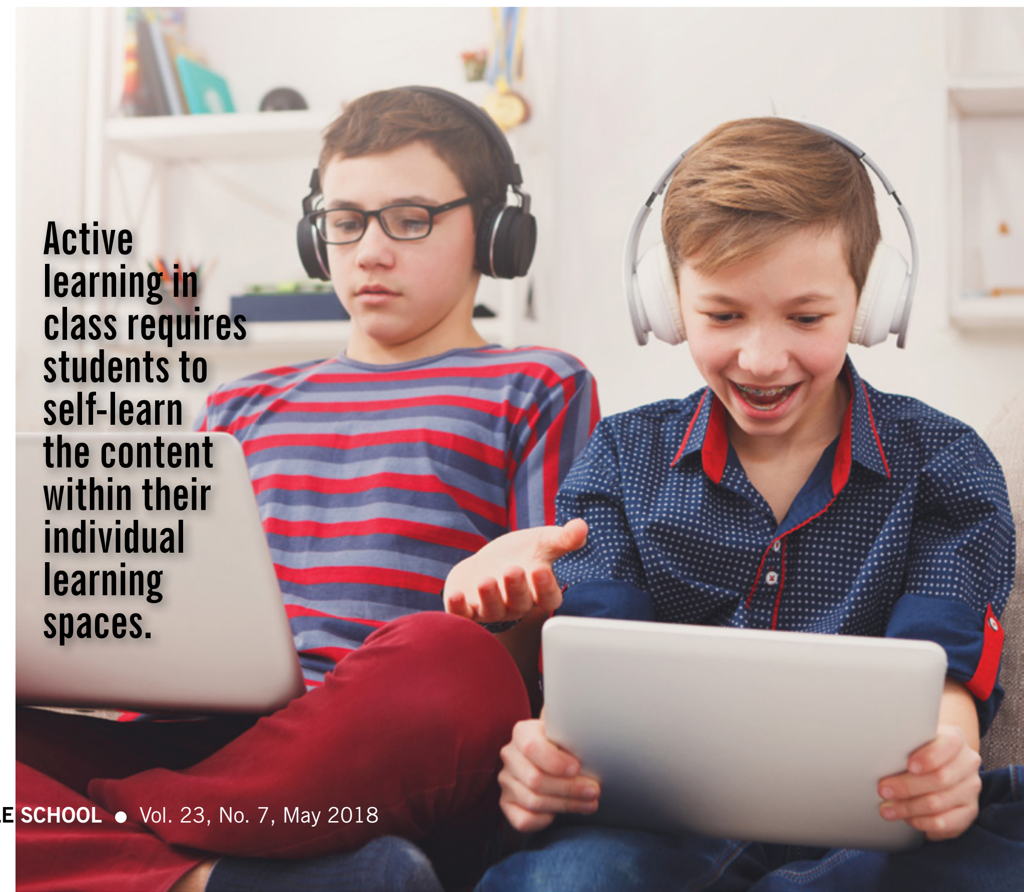
Studies of the effect that flipped instruction has had on student achievement show mixed results. In particular, Yong, Levy, and Lape (2015) did not find significant differences in student learning between flipped sections and interactive-lecture sections at Harvey Mudd College. In a study involving 11 sections of college algebra, Overmyer (2015) found that students of instructors using inquiry-based learning performed better in the common final exam. Jensen, Kummer, and Godoy (2015) found that it was an active learning mode rather than the flipped classroom that contributed to higher learning gains. Active learning in class requires students to self-learn the content within their individual learning spaces so that they are ready to apply what they have learned to solve problems independently and collaboratively in class. This article focuses on the self-learning portion of the flipped learning model, in particular, increasing students' intellectual engagement by requiring them to answer embedded questions as they watch math videos.

MATHEMATICS VIDEOS

A teacher who plans to flip his or her classroom may either search for an appropriate video for a topic or create a video. The advantages of a teacher-made video include the teacher's control over the mathematics content, the flexibility to pitch at a level best suited for the teacher's students, students' affinity for their teacher, and consistency in style and delivery. Advantages of using an open-source video include using the "best" available video for a particular concept, exposing students to different teachers and various teaching styles, saving the time it would take to create a video, and, possibly, expanding the teacher's knowledge of teaching. In general, a teacher may begin by first looking for an appropriate video or online resource. If there is not a video that meets both the lesson objectives and the students' needs, then the teacher can create his or her own video.

There are numerous instructional videos on learning mathematics available on the Internet for free access. Video-management websites, such as Edpuzzle, Zaption, and eduCanon, enable teachers either to create video lessons from public videos (e.g., YouTube, Khan Academy, Vimeo) or to create their own original videos. These websites offer various features, such as cropping, question embedding, and student performance tracking. The question-embedding feature allows teachers to insert questions for students to answer as they watch the video and automatically scores students' responses for forced-choice items. The class-management feature allows teachers to keep track of assigned videos, grade open-response items, review students' performance, and download student scores.

The first author (Lim) received an internal grant to develop resources for a hybrid section (50 percent face-to-face, 50 percent online) of a geometry-measurement course for prospective elementary and middle school teachers. For this project, he searched and/or created videos for students to self-learn. To enhance student learning, he embedded questions in the videos. After teaching this hybrid course for two semesters, he adopted the same model and developed resources for a second course on numbers and



Active learning in class requires students to self-learn the content within their individual learning spaces.

IMAGE ON PREVIOUS PAGE, MACHINEHEADZ/ISTOCK; STUDENTS WITH HEADPHONES, MILKOS/THINKSTOCK

operations. Among the students taking these two courses, typically more prospective teachers are in the elementary to sixth-grade band than in the fourth- through eighth-grade band.

After teaching two hybrid courses, Lim found that online math videos can be classified in five categories based on purpose:

1. To introduce a concept
2. To demonstrate a procedure
3. To explain why
4. To pose and solve a challenging problem
5. To illustrate using real-life scenarios

He produced 10 videos to help prospective teachers develop conceptual understanding and mathematical thinking. For online videos that focus on procedural knowledge, questions can be embedded to direct students to think about the meanings and ideas underlying the procedures.

EMBEDDING QUESTIONS

After creating more than 500 embedded questions and reviewing the questions and comments embedded by other users, Lim found that questions or comments can be embedded for three general purposes: (1) to enhance students' learning of the information presented in the video, (2) to assess students' understanding of what they are watching, and (3) to give instructions while students are watching the video. Most of the embedded questions in math videos, as of summer 2014, were for assessment and instruction purposes. Consequently, Lim wrote his own questions and embedded them to enhance student learning with the videos used in his courses.

A question or comment can be embedded at any point on the video timeline. There are generally two main formats: forced choice (e.g., multiple choice, true/false) and open response (e.g., fill-in-the-blank, essay). One

Fig. 1 Embedded questions can help students make connections.

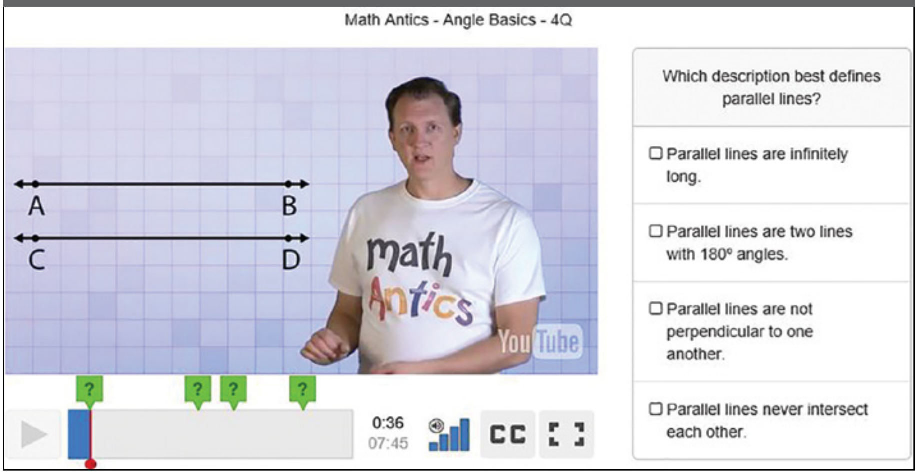
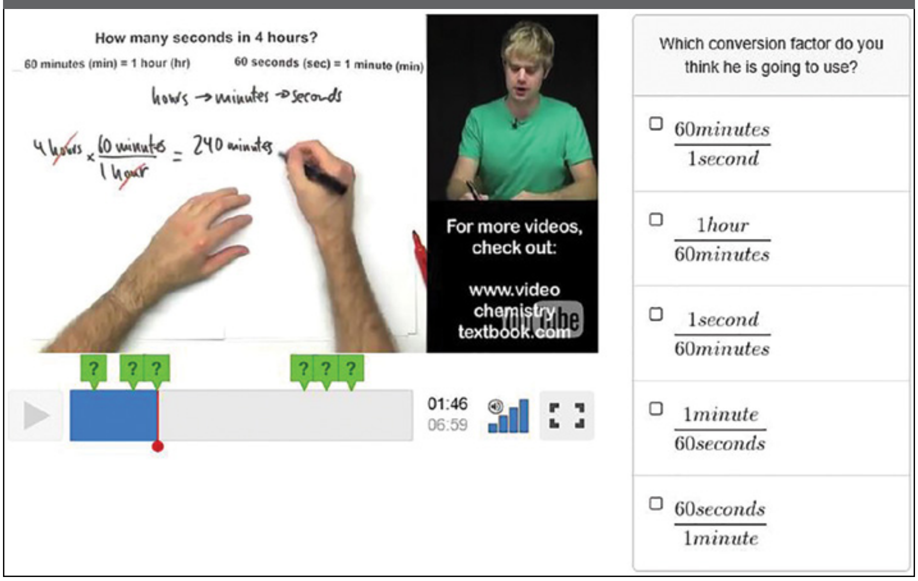


Fig. 2 This embedded question requires students to think about the next step.



advantage of forced-choice items is that they can be automatically graded and scored by the video-management software program. Another advantage is that it takes less time for the student to respond and to resume the flow of the video. It is therefore less disruptive to the student.

Questions can be embedded to help students gain different types of knowledge. On the basis of a preliminary analysis of 89 embedded questions in 21 videos on geometry and measurement, five types of embedded questions have been identified. Please note that the term "students" presented in the following discussion refers to prospective teachers and not middle school students.

TYPES OF EMBEDDED QUESTIONS

Factual Knowledge

When a question is posed in the video, the same question can be embedded to force students to think about it. For example, in a Math Antics video on angles, students will see the size of an angle of 1 degree; hear, "You might wonder if there can be any angle smaller than 1 degree"; and then answer the yes/no question, "Can there be any angle smaller than 1 degree?" Students who think in terms of whole numbers can learn from their mistakes that measurements can take fractional values.

Fig. 3 Students need to focus on what the fraction refers to.

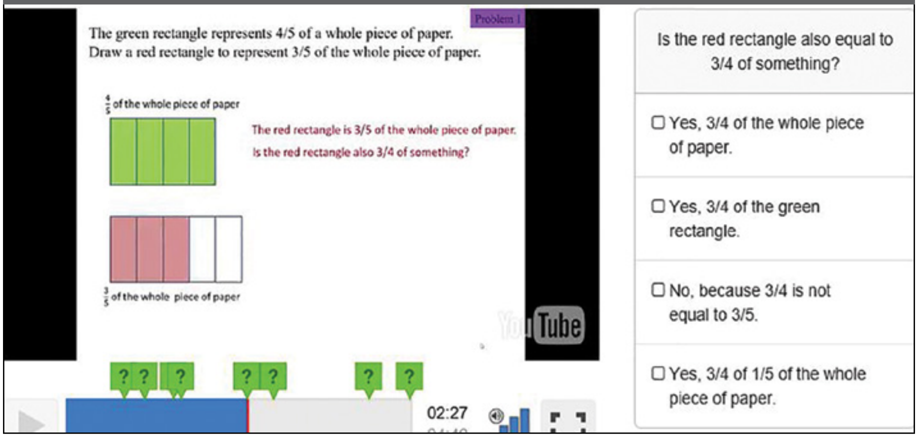


Fig. 4 This embedded question relates 3/5 and 3/4 symbolically.

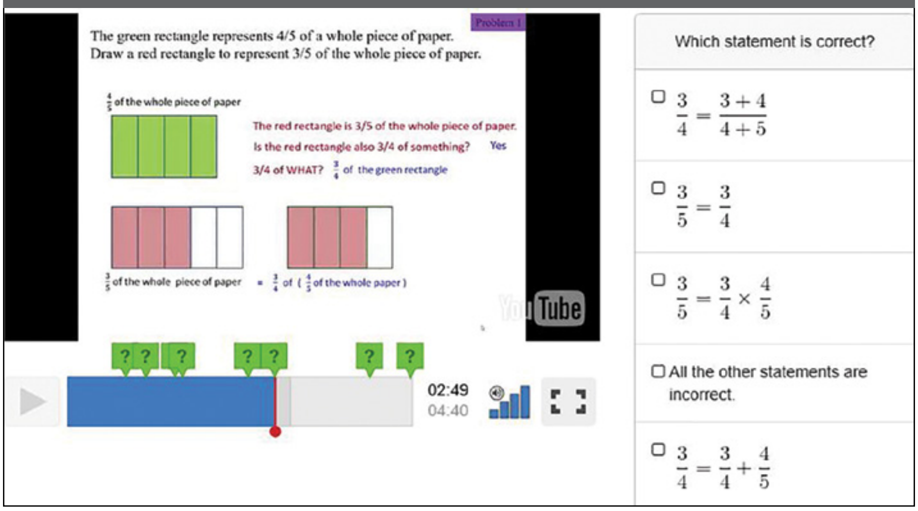
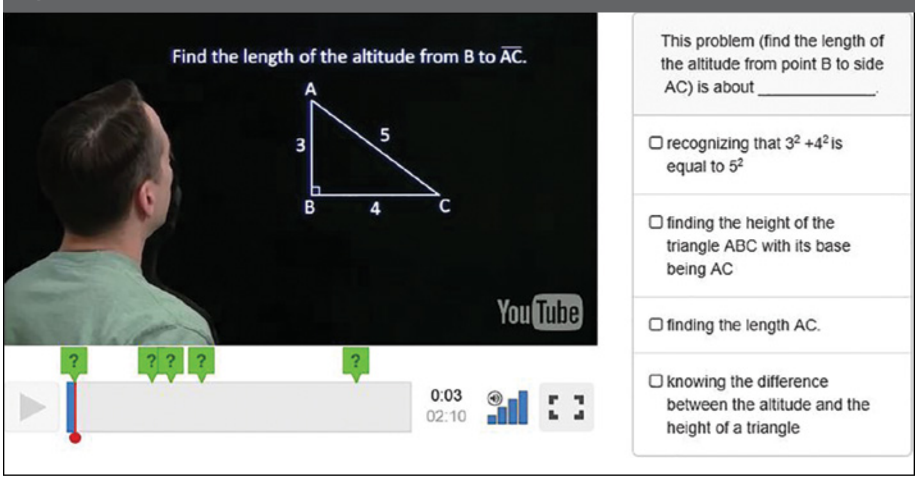


Fig. 5 Interpreting the problem statement is the basis for this embedded question.



In other situations, the teacher can pose a question to draw students' attention to a related idea and help them make connections. For example, after hearing that two lines point exactly in the same direction, as shown in **figure 1**, students are asked to infer a characteristic of parallel lines.

Procedural Knowledge and Skills

Numerous videos illustrate how to solve certain problems, but not many explain the concepts underlying the procedure. For example, the presenter in a Math Antics video describes the cross-multiplication method for comparing 7/8 and 4/5 but does not explain how 35 and 28 are related to the two fractions. A question can be embedded to draw students' attention to the meaning of 35 and 28. That is, if we are multiplying both fractions, 7/8 and 4/5, by some form of the number 1 (i.e., 5/5 and 8/8, respectively), then we are actually using the common denominator and comparing 35/40 and 28/40. On the other hand, if we are multiplying both fractions by 40, then we are indeed comparing 35 units and 28 units, which are not equivalent to 7/8 unit and 4/5 unit.

In certain situations, questions can be posed to engage students to anticipate a step just before it is presented in the video. The embedded question in **figure 2** asks students to think about the unit fraction that is appropriate for converting 240 minutes into seconds. This way, students get to engage with the ideas presented in the video instead of passively watching how a procedure is used to solve a routine problem.

Conceptual Knowledge

Certain concepts are epistemologically challenging for students because they may have multiple interpretations. For example, a quantity can be represented by different fractions depending on the referent for the fraction. In **figure 3**, the red region, which represents 3/5 of a piece of paper, can also be represented as 3/4 of something. The embedded question forces students to pay attention to the referent 3/4 by reflecting on the question and thinking about the answer before listening to the explanation presented in the video. The follow-up question in **figure 4** reinforces students' understanding that 3/5 of a whole is equal to 3/4 of 4/5 of the same whole; indirectly, it asks students to relate the two fractions symbolically, that is, 3/5 = 3/4 × 4/5. Among 40 prospective teachers, 30 percent selected the correct answer, 30 percent chose "3/5 = 3/4," and 18 percent chose "All the other statements are incorrect." Embedded questions offer students an opportunity to learn from their errors.

Task Comprehension

Learning the solution to a problem without comprehending the problem is fruitless. The embedded question in **figure 5** forces students to think about what the problem asks. Among 18 prospective teachers, only 44 percent realized that the problem is about finding the height of the triangle with *AC* and not *BC* as the base. It is interesting that 39 percent thought that the problem was about differentiating between altitude and height.

Mathematical Thinking

Problem solving inevitably involves reasoning and sense making because a solution approach to a problem, unlike a routine exercise, is not readily known to students. A question embedded in a video on how to solve a problem can help students think about the key idea related to its solution. For example, the solution for the problem in **figure 5** involves finding the area of the triangle in two ways. The embedded question in **figure 6** draws students' attention to a particular piece of information, namely, that angle *B* is a right angle, which is necessary to solve the

Fig. 6 This question focuses on the key idea for solving the problem.

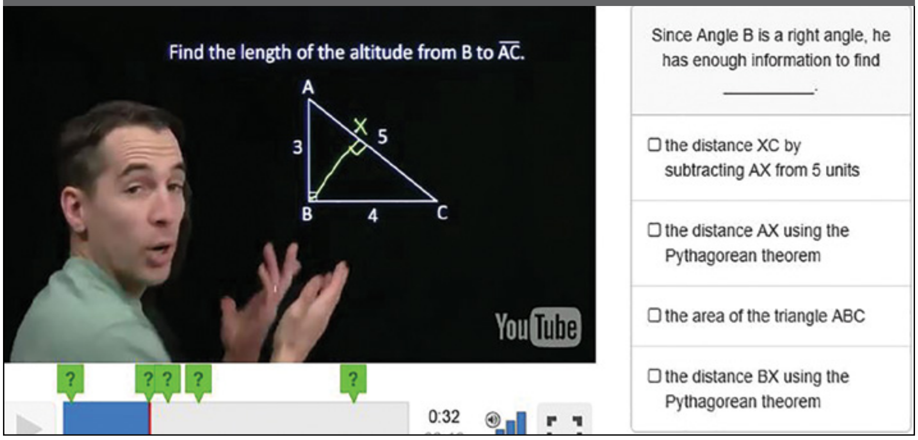


Fig. 7 This embedded question makes explicit an idea needed for the proof.

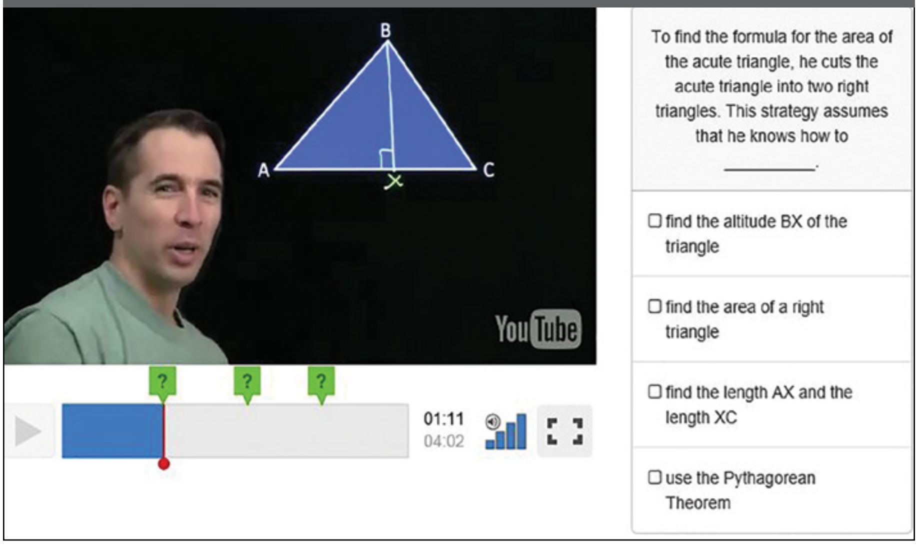


Fig. 8 This question makes sure that students understand the purpose of a particular step in a proof.

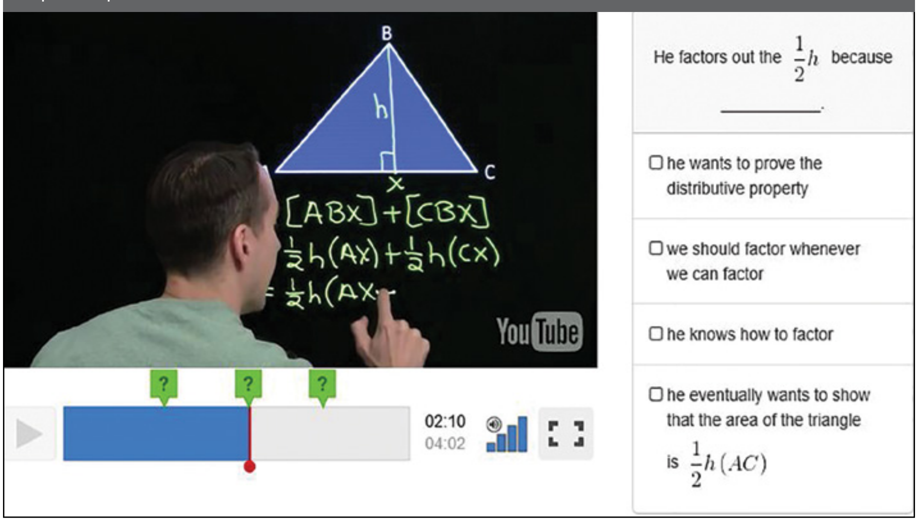
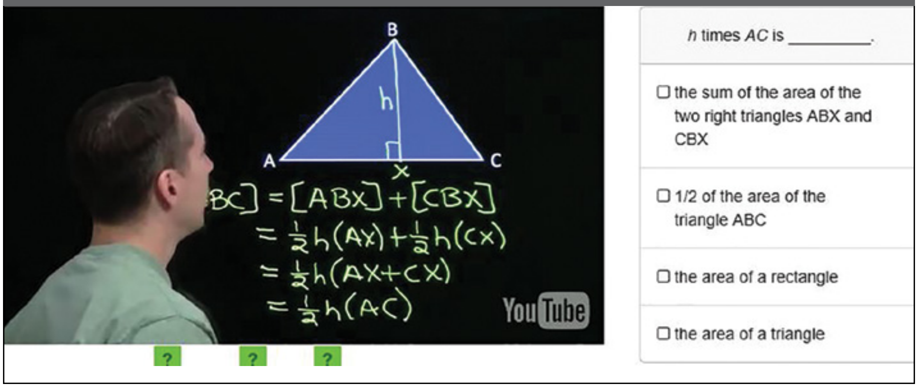


Fig. 9 Students must focus on the product $h(AC)$ to answer this question.



problem. Among 15 prospective teachers, only 27 percent chose the correct answer. Yet 40 percent chose "the distance *XC* by subtracting *AX* from 5 units," probably without realizing that it is even more difficult to find the length *AX*. Another 27 percent chose "the distance *BX* using the Pythagorean theorem," probably indiscriminately associating the right triangle with the Pythagorean theorem.

Sense-making questions can be embedded to draw students' attention to certain ideas, assumptions, or expressions. For example, the question in **figure 7** reinforces student understanding that the area of an acute triangle can be found by cutting it into two right triangles. It also fosters a particular kind of mathematical thinking—complex ideas are typically built using simpler ideas. The question in **figure 8** asks students to think about the reason for factoring out the $h/2$. This question fosters goal-oriented thinking, which in this case is to simplify an expression with a goal in mind, that is, to show that the area of the triangle is $bh/2$. The question in **figure 9** asks students for the meaning of the product $h \cdot AC$ in the expression $h(AC)/2$. Surprisingly, only 26 percent of 19 prospective teachers recognized the product as the area of a rectangle. Questions, when embedded strategically in videos, can foster mathematical habits of mind such as being goal oriented (Voskoglou 2011) and attending to meaning (Thompson 2013).

Let's Chat about Flipped Learning

On Wednesday, May 16, 2018, at 9:00 p.m. ET, we will expand on "Flipped Learning: Embedding Questions in Video" (pp. 378–75), by Kien H. Lim and Ashley D. Wilson. Join us at #MTMSchat.

We will also Storify the conversation for those who cannot join us live. Our monthly chats fall on the third Wednesday of the month.

CONSIDERATIONS FOR EMBEDDING QUESTIONS

As users of other people's videos, teachers have no control over the information presented. Embedded questions allow teachers to enhance student learning by including additional information related to the content of the video. For example, the question in **figure 1** helps students learn that parallel lines not only "point in the same direction" but also will never meet.

Teachers can embed questions before or after a piece of information is presented in the video. Posing an embedded question before the video presentation can—

a. prepare students for what is to come by drawing on prior knowledge (e.g., **fig. 6**);
b. allow students to make a prediction and learn from mistakes (e.g., **figs. 2** and **3**); or
c. provide an opportunity for students to practice thinking and problem solving (e.g., **fig. 6**).

Alternatively, a question can be embedded immediately after an idea is presented in the video to—

a. ensure comprehension of the idea (e.g., **fig. 3**);
b. encourage thinking about the idea in greater depth (e.g., **figs. 1** and **4**);
c. make connections (e.g., **figs. 1** and **4**), or
d. provide practice in applying a newly learned idea (e.g., **fig. 2**).

An embedded question inevitably breaks the flow of the video and may disrupt students' train of thought. When considering whether to embed a particular question, teachers may think about their responses to these questions:

- What is the purpose of embedding this question?
- How does this embedded question increase student engagement or enhance student learning?
- Will it enhance—or break—the students' flow of thoughts in relation to the idea presented in the video?

If a question is embedded solely for assessing student understanding, then the question may be better posed after students have watched the video rather than while they are watching it. If a question is embedded to increase student engagement, then teachers may consider whether students would find the question interesting and not too overwhelming. Teachers may need to consider the tension between fostering positive affect toward learning (e.g., posing straightforward questions that most students would answer correctly and feel good about their learning) and enhancing mathematical learning (e.g., posing challenging questions that would deepen student understanding). If a question is embedded to enhance student learning, then teachers would need to identify the aspect of mathematical knowledge (factual, procedural, conceptual) or thinking (task comprehension, reasoning, sense making, problem solving) at which the question is directed. On the one hand, thinking-oriented questions can enhance students' process skills; on the other hand, such questions are more likely to break the flow of ideas presented in the video.

EMBEDDING QUESTIONS TO ENHANCE LEARNING

When we started using math videos in fall 2014, we found that the embedded questions, created by Edpuzzle users who are mainly math teachers, were mostly intended to help students remember something that was presented in the video or solve a similar problem using the procedure shown in the video. These types of questions mainly assess whether the student was paying attention to the video and knows how to apply the procedure. Such questions do not intellectually engage students to think deeply about what they are watching. This article introduces different types of embedded questions that can enhance students' learning as they watch videos. An awareness of various pedagogical reasons for embedding a question can expand teachers' repertoire of the kinds of questions they can consider embedding should they wish to assign math videos for their students to watch, especially in a flipped learning model.

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