HOW TO MAKE QUESTIONING WORK FOR YOU

Effective Questioning in the ChE Classroom

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The classroom atmosphere in many college lecture halls is far from ideal. Many students are passively involved in learning the material—if they are involved at all. When called upon, a typical student often responds with as few words as possible or simply waits for the professor to answer for him or her. Wouldn't it be great if students walked into class excited and ready to go? If they discussed the material in class and were actively involved in their own learning?

Actually, the two situations are not that far removed from each other, and two small teaching behaviors could close the gap considerably. Just two changes can result in increased student participation, increased student interest, and increased student learning. The first teaching change involves asking better questions; the second change is waiting an appropriate amount of time for the students' response.

One problem is that many questions frequently encountered in a college lecture hall are short-answer in nature, *e.g.*, there is only one correct response and it doesn't require much thought to come up with it. In my experience, professors rarely ask a question that requires the student to synthesize an answer. Even when a good question is posed, most professors fail to provide an appropriate amount of time for the student to synthesize an answer—and they end up telling the students the solution to the problem.

There are five types of questions that are usually appropriate:[1]

Attention-focusing questions • These are typically short-answer questions; they ask such things as "have you seen?" "did you notice?" or "what happens if?" Measuring and counting questions such as "how often?" and "how many?" are also short-answer in nature.

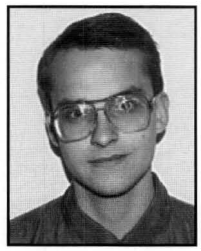
Comparison questions • These are extended-answer/open-ended questions and are typically qualitative in nature. Examples include "how are...and...similar?" and "how do they differ?"

Action questions • These are the "what happens if?" questions and are usually open-ended in nature.

Problem-posing questions • Questions of this nature are typically phrased in a manner similar to "can you find a way to?"

How and why questions • These questions are frequently misused and should be avoided in most circumstances. Such questions include "Why do you think?", which is highly open-ended. The questions typically result in a teacher telling the students they are right or wrong, depending on what they say, and can do more harm than good in terms of student self-esteem.

Unfortunately, randomly asking the right type of question alone does not solve the problem of passivism in the classroom. A good questioning technique is also needed. The questions must be of an appropriate level of difficulty so the students will find them interesting, and they must follow a progression that is logical to the students. Since students are being exposed to the material for the first time, jumps that may seem logical to the instructor could leave student comprehension behind. In order for students to learn, the order of



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questions must make sense to them. Care should be taken to ensure that jumps in logic are not too large.

One questioning model that has been proposed (by no means the *only* appropriate model, however) is the HRASE (read as "harass") model.[2] Using this model, the first question should relate the upcoming questions to the

- **H**istory of the student, his or her past experience. Appropriate questions include "What did you find?" and "What happened when?" They should be relatively easy to answer but should require more than a yes/no answer. After a history has been developed with the students, the next step is to have the students seek
- **R**elationships and patterns with questions such as "How does this compare to?" and "What is a common theme in your results?" By drawing relationships, students are logically prepared for the next step, which is finding an
- **A**pplication for the knowledge. These questions include "How could you use this?" and "If you wanted to do that, how would this help?" After the students have discussed some applications of the knowledge, the next step is to make
- **S**peculations about a different situation. Appropriate questions include "What if we did this instead?" or "If we wanted to prevent that from happening, what could we do?" After the students have made some speculations (and perhaps tested them), the next step is an
- **E**xplanation for the experience. Appropriate questions for this include "How does that work?"or "What causes that to happen?" or "How would you change your explanation if I changed. . .?"

To summarize, the HRASE model is a questioning strategy that provides a logical order for asking questions. To demonstrate an example of HRASE at work, consider a mass transfer course where the students have just finished a laboratory on batch flash distillation. To lead into a multistage process, the following series of questions could be used.

H *What happened when we flashed an ethanol-water mixture?*

A question such as this calls on the students' past experience and brings to mind an actual event to which they can all relate.

R *How does this compare to the batch distillations you have done in organic lab?*

This question causes the students to relate the material from the mass transfer course to other courses they have taken. It also encourages them to compare and contrast the two processes.

A *If you wanted to separate benzene and toluene, what problems would you encounter.?*

This provides an opportunity for the professor to assess student understanding. He is asking the students to apply knowledge they already have to a new situation. If he is not satisfied with the responses, the professor can send the students to the teaching laboratory and let them encounter the problems.

S *What would happen to the vapor phase if I added a partial condenser at the top? How could we find evidence to support that?*

This requires the students to speculate—an unknown. Care must be taken (if future participation of the students is desired) to ensure that the students do not feel embarrassed by "wrong" responses. To minimize such a situation, one approach is to put all the student predictions on the board, ask the students to choose the one they like most, and then test it as a class exercise. In a teaching laboratory, a small-scale model of a flash drum can be used to test the student predictions. If a teaching assistant has the equipment ready to go when the students arrive, the demonstration would only take a few minutes.

E *What causes this to happen?*

This type of question gives the professor an idea of student misconceptions since their explanations will reflect their misconceptions. When one or two students voice a major misconception, it is likely that others in the class hold the same misconception. Rather than telling students they are wrong, ask them to make predictions (another **S**peculation question) about what they would expect to see if this were the case, and have them do this as part of a laboratory exercise. Notice that such an approach results in a learning-cycle approach to teaching, which research has shown to be very effective.[3,4]

If used appropriately and consistently, this model and others like it have the potential of increasing desirable stu-

dent behavior. There are times, however, that even when asking all of the "right" questions at the "right" time will still result in no response from the students.

Instructors will frequently ask a question and then wait less than one or two seconds for the students to respond, regardless of the type of question. Increasing the wait-time has a variety of effects:[5]

- *Length of student responses increases by up to 700%*
- *Students demonstrate more logic and provide support for arguments*
- *Students speculate more*
- *Students ask more questions and propose more experiments*
- *Student-student exchanges increase*
- *Student responses of "I don't know" (or no response) decrease*
- *Students stay attentive for longer periods of time*
- *Students volunteer more*
- *Student confidence increases*
- *Achievement on written measures improves*

These positive outcomes relate to many of the common goals shared by chemical engineering faculty. Specifically, students have more opportunities to demonstrate the depth of their understanding of fundamental chemical engineering concepts; they practice effective communication skills; they are better able to apply chemical engineering concepts; and they are better prepared to encounter new situations. Obviously, effective use of wait-time offers many benefits in the chemical engineering curriculum.

There are two types of wait-time. *Wait-time one* refers to the amount of time an instructor gives a student to respond to a question before moving on to another question. *Wait-time two* refers to the amount of time the instructor waits after a student has responded to a question to allow other students to respond. In order for the above benefits to be fully realized, both types of wait-time should be used and the students should be made aware of the instructor's expectations.

After asking an open-ended question, at least three seconds of *wait-time one* should be provided for the students to formulate their responses. Longer time can be used for more complex questions. In fact, a wait-time of over a minute is not unreasonable for engineering problems. It allows the student to formulate a coherent response in which he or she has considered some of the specific details and allows for better discussions to ensue. Beware, however, of the perception of time. One minute of silence in a classroom can seem like an eternity, especially to the instructor. If a problem should take more than a minute to reason through, don't be afraid to use a watch.

After the first student has responded, wait again. At least three more seconds of wait-time are required for *wait-time two.* For the first few times that *wait-time two* is used, the instructor may need to prompt the students to respond to each other. An appropriate question might be, "What alternatives do you have to his (her) idea?" or "What are the problems/benefits of that idea?" Research also shows that giving a student a chance to respond without interruption and without immediate rejection/acceptance can improve the student's self-esteem and the quality of his or her learning.[5-7]

Once an instructor starts using wait-time, he or she should talk to others about the experience and have outsiders evaluate it by measuring the quality and length of responses both before and after wait-time. This allows the instructor to get a second opinion on the value of wait-time and also helps to make the changes more lasting—if there is corroborative evidence that the wait-time is effective, the instructor is far less likely to revert to the original wait-times of less than one second.[5]

In addition to the outside review, students should also be asked to evaluate the experience. There are two reasons for this: first, the instructor can get an idea of what is an appropriate length of time for *wait-time two*; and second, the students will have an opportunity to inject some of their own input into the class, which frequently has many other positive advantages.[8]

Even with adequate wait-time and appropriate questions, there are still occasions when students will feel too threatened to respond to questions. Typically, highly speculative questions tend to increase student anxiety and result in less participation, but such questions are very relevant to assessing student understanding and student progression. One way to overcome student anxiety is to ask a lot of speculative questions. Let the students work on the problem by themselves for a brief period of time, and then ask them to discuss their ideas with the person next to them; next, ask them to share their ideas with the rest of the class. The result of this procedure is that students are less likely to feel anxious about the possibility of proposing a wrong idea. If the student is still nervous about sharing in class, his or her partner can present the idea instead.

If the professor accepts all ideas and writes all of them down on the board (even the incorrect ones), the students will begin to feel comfortable when expressing an opinion or an idea in this class. That is not to say that a professor should let just any comment be construed as correct. Rather, after all of the ideas are on the board, he should go back and evaluate them for the class. This distances rejection from the student—that is, the student is less likely to feel rejection in front of the class. Over time, such an approach can result in students proposing speculative ideas without having to first

consult with a peer, and it can lead to student realization that there is a time for speculation—even incorrect speculation.

By asking more appropriate questions and asking them in a logical sequence, it is possible to improve the quality of in-class student interaction. Furthermore, such interaction comes at a low cost, and it can improve both the self-esteem of the students and their learning potential. In addition to asking the right type of question, it is essential that wait-time be used to allow students to formulate and work through their responses. *Wait-time one* allows students enough time to come up with an appropriate response, and *wait-time two* allows students to prepare a response to other students responses; the result is a more student-centered classroom.

The instructor should use both student and peer evaluation to help him realize the full potential of the results. By using these simple techniques in the classroom, the quality of instruction can increase dramatically.

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