Question Design Patterns

A toolkit of effective question types to meet a variety of teaching goals

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Question design patterns are general ways of building TEFA questions that successfully achieve specific instructional aims. They are not quite "fill in the blanks" templates, but they are more specific than general strategies or qualities. Some patterns suit certain circumstances and instructional objectives better than others.

The goal of each pattern is to direct students to engage in a particular kind of thinking, since different kinds of thinking both reveal and develop different aspects of students' knowledge. The patterns have been divided into groups promoting similar kinds of thinking. *Caveat 1:* The boundaries between patterns, and also between groups, are neither sharp nor well-defined. *Caveat 2:* This list of patterns is not complete, though we believe it contains most of the common types as well as a few unusual, stimulating ones. Our goal is to provide a useful tool for stimulating ideas, not a clean taxonomy for categorizing questions. A question may very well fit two or more patterns.

We hope that reviewing this list will help you when you know what you want to accomplish in class, but aren't sure how best to do that, or when you feel your CRS use is stuck in a rut and you want to try something new.

The reader will note that no "recall the fact" or "demonstrate ability to execute a process" pat-

Why "Design Patterns"?

Architects and structural engineers solve problems when they design: how to provide a certain desired functionality, given specific constraints, as efficiently (and often attractively) as possible. If the same general kinds of problems come up again and again, differing only in superficials, why should designers start over each time? That was the premise of *A Pattern Language: Towns, Buildings, Construction*, a 1977 book by Christopher Alexander, Sara Ishikawa, and Murray Silverstein of the Center for Environmental Structure in Berkeley, CA. The book contained 253 architectural design patterns coupled to specific needs and circumstances. It provides general descriptions and pictures, and leaves the specific details to be worked out according to a specific project's environment. More than 25 years later, the book remains one of the best-selling books on architecture.

In 1987, Kent Beck and Ward Cunningham carried the idea into software engineering. Here too, they argued, similar programming problems arise over and over; why should programmers re-invent soluterns are included. While occasionally useful, these do nothing to exercise student *thinking*.

Evaluative Thinking

SOLVE

– *If X, determine Y. [list choices, or numeric response]*

This apparently "right/wrong" pattern, often over-used, can be useful at times: perhaps to quickly check for competence, or to set up a discussion, or to motivate a new idea or technique, or to sensitize students to the importance of a particular assumption. ***Variant:*** Ask for the answer option "closest to" the true result. ***Variant:*** Provide a "none of the above" option, and have it be the best choice often enough that students learn to respect it.

EVALUATE

– *[Context.] Which of the following statements are true? Pick all that apply. [list assertions]*

Students are accustomed to being told, and to remembering, what is true. They are less used to assessing the truth of statements, but this is a necessary higher-level skill for scientific and mathematical thinking. ***Variant:*** List similar statements that all seem reasonable, so students must focus on the significance of the differences. ***Variant:*** Include a reason in the assertions ("*X*, because *Y*"), so students must evaluate the truth of the assertion and of the reason.

ENUMERATE

– *How many X are Y? [list possible integers, or numerical response]*

– *How many X does Y have? [list or numerical response]*

Unlike for SORT/CLASSIFY, students are not given a list of possible *X*, so they are involved in *generative* thinking. The pattern is useful for helping them learn to identify relevant things (forces, components, characteristics, etc.). The situation should usually be clear-cut and simple, or counting possibilities can become unrealistic. ***Variant:*** Include options like "less than *N*," "more than *N*," or "impossible to determine."

Comparative Thinking

JUDGE SIMILARITY

– *Which of the following X is most like Y?*

– *X is to Y as Z is to which of the following?*

This pattern stimulates compare-and-contrast thinking, which is powerful for helping students explore and relate things, and also for revealing how they perceive or think about something. Questions in this pattern have two levels of comparison: students must compare each answer choice to the standard (*X*), and must compare the response choices to each other based on how well they fit the standard. ***Variant:*** Use a photo or other alternative representation for *Y*. ***Variant:*** Make it a "big stretch," with *Y* a very different kind of thing than the options.

SORT/CLASSIFY

– *Which of the following are X? [list cases, things, or situations]*

– *For which of the following is X true?*

Sorting or classifying helps students begin to structure their knowledge, sensitizing them to similarities and differences. It also helps you discover what features they are keying on, which may not be the features you consider important. ***Variant:*** Don't provide a criterion, but simply ask students to divide a set of things into two subsets, and then explain the criterion they chose.

RANK/COMPARE

– *Which of the following (is/has/would have) the (most/least/greatest) X? [list]*

– *Which X is most Y? [list]*

Like SORT/CLASSIFY, this pattern elicits comparative thinking, but it does so by having students compare the relative magnitudes of something rather than membership in a set. It is particularly useful when helping students to develop a sense of the strength of effects. ***Variant:*** Have students pick the 2 (or 3 or etc.) largest/

tions each time? In 1994, Erich Gamma et al. published *Design Patterns: Elements of Reusable Object-Oriented Software*, describing 23 classic software design patterns that can be adapted to different programming languages and specific circumstances. Several other collections of software design patterns have since appeared.

We believe that TEFA-using teachers, too, face the same instructional problems over and over, with the specific topic at hand being the only significant differences. "Good" TEFA questions are effective for specific reasons, and their design can be generalized and applied to help create good questions on other topics.

smallest cases. ***Variant:*** Have students rank the entire set, either using multiple choice and having each option represent a possible ordering, or by using *Interwrite Response*'s "Answer Series" question type.

COMPARE WAYS

- *Which X is best for accomplishing Y? [list possibilities]*
- *In order to X [most Y], which Z (should/could) you use? [list]*

This pattern also involves comparative thinking, and helps students reflect upon and structure their knowledge as a "toolkit" of useful ideas and techniques. You can ask about models, principles, procedures, strategies, problem-solving choices, experimental tools, reagents, etc. ***Variant:*** Ask which can "most efficiently" or "most reliably" be used to bring in different criteria for judgment, or leave the criteria unstated to allow different interpretations of "best" to arise in discussion.

PREFER

- *If you (had/wanted) to choose one X in order to Y, which would you pick? [list options]*
- *If X, would you Y? [yes, no, it depends]*

This pattern can be powerful in making a topic more personal to students, and in helping you understand what thinking they bring to it. ***Variant:*** Include emotionally loaded and conflicting factors to create a difficult dilemma. ***Variant:*** Omit "it depends" from the second version in order to force students to commit, at least provisionally, to a hard choice.

Representational Thinking

RELATE REPRESENTATIONS

- *Which X best (describes/represents/fits) Y? [list possible representations]*

Alternative (often graphical) representations are powerful tools for scientific and mathematical thinking, often under-used by students. Questions that require connecting different representations help make them useful, and solidify understanding. The choices can be pictorial diagrams, topic-specific diagrams like cardiograms, schematics, equations, graphs, etc. ***Variant:*** Include an "it depends" option to stimulate consideration of contingencies—but be careful this doesn't distract from your primary point.

DEPICT

- *[Have students draw or otherwise represent a specific situation or process.] Which of the following is most like your drawing? [list possibilities]*

Having students draw—forcing them to re-represent something—helps them digest it, and the results can be very revealing for you, especially if you can walk around and inspect their drawings. It can also help them learn to see visual representations as a thinking tool they can use. ***Variant:*** Include a "none of the above" option to handle unanticipated (often interesting) cases.

GESTALT

- *Which of the following might X represent? [list possibilities]*

This pattern is the inverse of DEPICT. *X* is a graphical or other non-textual representation of some kind, possibly quite ambiguous, and the list of choices are situations or things that it might fit. *X* can be a Venn diagram, schematic, spectrum diagram, sonogram, cardiogram, DNA test result, equation, graph, or even an inkblot. ***Variant:*** Use "choose all that apply" to unleash creativity, at the expense of rigorous evaluation and comparison of options. ***Variant:*** Present the question without answer options, and have students brainstorm possibilities; then collect a set of possibilities, number them, and have students choose their favorite via CRS.

Causal Reasoning

DETERMINE IMPLICATION

- *If you want X, should you Y? [yes, no, it depends]*

This pattern engages students in the question of what their new knowledge means. "Should" is a power word that can bring in a range of criteria and considerations, opening up rich discussion. ***Variant:*** For a tough dilemma, omit the "it depends" option to eliminate the easy out and force at least provisional commitment to a side.

PREDICT & VERIFY

- *[Present a concrete situation.] What will happen if Y? [list possibilities]; after students answer, do a demo or otherwise confirm/refute their predictions*

This pattern asks students to apply causal reasoning or their intuition to a system or situation, in order to reveal, test, and refine that reasoning and intuition and help connect it to scientific or mathematical ideas. ***Variant:*** Have students predict via CRS responses, discuss their reasons, poll again, then do the demo/ check. ***Variant:*** Confront deeply-held beliefs and biases with counterintuitive evidence.

DIAGNOSE

– *[Describe a case.] Which of the following (might/is most likely to) be the (cause/problem/ reason)? [list possibilities]*

This pattern gets students to apply their knowledge in a (hopefully) engaging, deductive manner. It also develops the scientific habit of hypothesis inference. A natural follow-up question is to ask how students might test their diagnoses or hypotheses (cf. *COMPARE WAYS*). ***Variant:*** Include "other" as an option to open speculation about other possible causes.

RECOMMEND

– *[Describe a situation.] What (decision/advice) would you (make/give)? [list possibilities]*

Similar to *DIAGNOSE*, this pattern asks students to apply their knowledge and consider its implications. It encourages more open-ended thinking than *DIAGNOSE*. ***Variant:*** Mix multiple ideas or factors, especially ones that suggest conflicting recommendations. ***Variant:*** Address personally meaningful or emotionally loaded topics and beliefs to stimulate engagement and help the subject hit home. ***Variant:*** Include an option for "other" to encourage creative thinking.

HYPOTHESIZE CHANGE

– *[Describe a situation.] How (would/might) X differ if Y?*

This is similar to *INFER FROM A MODEL*, but doesn't require a detailed model (though we can argue that a model is still implied). It focuses students on the causal effect of specific factors, which can help them understand relationships between ideas.

Model-Based Reasoning

INFER FROM A MODEL

– *[Describe or summarize a model, system, or mechanism.] If X, will Y? [yes, no, it depends]*

– *[Describe…] What will happen if Y? [list possibilities]*

– *[Describe…] What X is necessary for Y to (happen/be true)? [list possibilities]*

– *[Describe…] (Where/how/ when) should X be Y in order to Z? [list possibilities]*

Many sciences involve teaching students about specific models, or about tools for creating models for situations: cellular processes, physiological systems, food webs, physical models, etc. Even algebraic equations can be conceived as models for something. Asking students to make inferences about something based on a model—to reason with the model—both develops and illuminates their understanding of the model. The model presented can be known, new to students, or a new elaboration or variation of a familiar one. ***Variant:*** Provide the model graphically, rather than textually.

EXTEND A MODEL

– *[Describe or summarize a familiar model.] How must the model be (extended/changed) in order to Y? [list possibilities]*

To see how well students really understand a model of something, and to help them practice real scientific thinking, ask them to change it to explain or predict something new, or to model the original thing better. ***Variant:*** Combine with *COMPARE WAYS* by listing several models or systems, and asking which could most easily be modified to fit the new situation.

Introspective Thinking

REFLECT

– *How (confident/confused) do you feel about X? [list various degrees/amounts]*

– *Which of the following are you (confused/uncertain) about? [list ideas/procedures]*

– *How do you (do/like to) X best? [list possible preferences]*

– *Etc…*

Any question that directly asks students for an honest reporting of their feelings, opinions, or self-assessment of something fits this pattern. It can help you better understand your students and where they are at the moment, and can help your students become more self-aware. The question can inquire about self-evaluation of knowledge and understanding, preferred tools and procedures learning styles, hopes and fears, or many other things. Discussion is not necessary, and is often inappropriate, unless students want an opportunity to explain themselves or vent more extensively.

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