**Table S1**

Items used to prompt students to draw out their ideas about groundwater and how it is naturally stored underground.

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| --- | --- | --- |
| **Time point** | **Item or prompt** | **Type of task the item or prompt appears in** |
| T1 | In preparation for next week, draw and label a picture of how water\* is naturally stored below the ground.  \*water that is pumped from the ground to drink | Free-sketch activity |
| T2 | How are all three aquifers related to each other in a “bigger picture”?  Let’s give it a try! Use color pencils if you brought some. On your handout:  Shade in where the each of the three types of aquifers would occur. Be sure to label each aquifer that you shaded in.  Note: There is a little house sketched in for reference, to help you visualize the size and extent of the aquifers. | Delimited-sketch activity |
| T3 | In the figure below, (1) draw in the confined, perched, and unconfined aquifers; (2) draw in a drinking water well that pumps water out of the unconfined aquifer; (3) label each aquifer, the water table, and the potentiometric surface; and (4) in the space below, answer the following question: “What does it mean for a rock to be impermeable?” by completing the sentence: For a rock to be considered impermeable, it means that …. | Delimited-sketch item on mid-term exam |
| T4 | Draw and label a sketch that shows the position of the following geologic structures with respect to one another: confined aquifer, unconfined aquifer, perched aquifer, water table, potentiometric surface, impermeable layers, porous and permeable layers, and wells as needed to illustrate certain relationships. | Free-sketch item on final exam |

**Table S2**

Items in pre- and postcourse survey that solicit information about social dimensions of students’ attitudes towards learning.

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| **Survey** | **Item** |
| Pre and post | I like to work alone.  [Likert scale: Strongly agree, Agree, Unsure, Disagree, Strongly disagree] |
| Pre and post | I like to work with others.  [Likert scale: Strongly agree, Agree, Unsure, Disagree, Strongly disagree] |
| Pre and post | I strongly prefer to …  [Multiple-choice: Alone, With others, Both, No preference] |
| Post | What did you like BEST about this course?  [Free-response] |

**Table S3**

Rubric describes the method of scoring the free-form and base-form concept sketches.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Type of aquifer** | **Location criteria** | **0 point** | **0.25 point** | **0.5 point** | **1 point** | **1.5 points** | **1.75 points** | **2 points** |
| Perched aquifer | rests on layer of impermeable\* rock above water table or an unconfined aquifer | Not shown | Incorrect location (e.g., inside unconfined aquifer) | Partially correct. Above unconfined AQ, but does not have bottom impermeable layer. | Correct location, but incorrect lateral extent (i.e., drawn as a "packet") or points at general location | NA | NA | Correctly positioned in terms of location and lateral extent |
| Unconfined aquifer | rests on layer of impermeable rock and/or has vertical pore connection to atmosphere | Not shown | Incorrect location (e.g., envelopes a confined aquifer) | Partially correct. Below unsaturated zone, but does not rest on impermeable rock layer. | Correct location but incorrect lateral extent (i.e., drawn as a "packet") or points at general location) | NA | Mostly correct location, but vertical extent abuts with a permeable layer thus creating a confined AQ | Correctly positioned in terms of location and lateral extent |
| Confined aquifer | rests between two layers of impermeable rock and has no vertical pore connection to atmosphere | Not shown | Incorrect location | Partially correct. Has top impermeable layer, but not bottom impermeable layer. | Correct location but incorrect lateral extent (i.e., drawn as "packet") or points btw 2 impermeable layers) and/or incorrect vertical extent (i.e., GW does not fill vertical space btw impermeable layers) | Correct or mostly correct lateral extent, below unconfined aquifer but missing bottom impermeable layer | Correct location and mostly correct lateral extent | Correctly positioned in terms of location and lateral extent |

\*impermeable = includes very low permeability

NA = no description associated with these point attributions