Supplemental Material

CBE—Life Sciences Education

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Table S1: Correlation Coefficients for Rubric Categories

	Correct Molecular Products	Carbon Alone	Molecular Mechanism	General Metabolism	Matter Converted to Energy	Exhalation	Excretion	How to Lose Weight
Correct Molecular Products	1 (.)	-.218** (0.000)	.156** (0.000)	-0.01 (0.73)	-.392** (0.000)	.653** (0.000)	0.036 (0.215)	-.241** (0.000)
Carbon Alone	-.218** (0.000)	1 (.)	-0.018 (0.531)	-0.05 (0.085)	-.115** (0.000)	.156** (0.000)	0.018 (0.526)	0.002 (0.955)
Molecular Mechanism	.156** (0.000)	-0.018 (0.531)	1 (.)	-.177** (0.000)	-.098** (0.001)	0.013 (0.653)	-0.018 (0.545)	.114** (0.000)
General Metabolism	-0.01 (0.73)	-0.05 (0.085)	-.177** (0.000)	1 (.)	.075** (0.01)	-.074 (0.011)	0.018 (0.528)	.075 (0.01)
Matter Converted to Energy	-.392** (0.000)	-.115** (0.000)	-.098** (0.001)	.075** (0.01)	1 (.)	-.476** (0.000)	-.058 (0.045)	.192** (0.000)
Exhalation	.653** (0.000)	.156** (0.000)	0.013 (0.653)	-.074 (0.011)	-.476** (0.000)	1 (.)	0.019 (0.51)	-.277** (0.000)
Excretion	0.036 (0.215)	0.018 (0.526)	-0.018 (0.545)	0.018 (0.528)	-.058 (0.045)	0.019 (0.51)	1 (.)	-0.004 (0.904)
How to Lose Weight	-.241** (0.000)	0.002 (0.955)	.114** (0.000)	.075 (0.01)	.192** (0.000)	-.277** (0.000)	-0.004 (0.904)	1 (.)

**. Correlation is significant at the 0.01 level (2-tailed).

Five- and Six-Category Responses Trace Matter across Scales with Varying Specificity

We were very interested see how those responses containing the largest number of ideas ("five- and six-category" responses) traversed scales. As mentioned in the main text, although we have 8 rubric categories (Table 1), the maximum number of ideas a response can contain is six. In the five-category responses (n = 17), the organismal *Exhalation* idea was the most commonly occurring, followed by the molecular/cellular idea of *Correct Products* (Figure S1). There was a tie of two ideas for the third-most-commonly occurring: *Excretion* and *How to Lose Weight*, both at the organismal level. It is important to note that these four categories did not occur together in all responses. Some responses traced matter across scales in a very detailed manner. For example, the following response names the process, and then traces the matter through important intermediates (e.g., pyruvate, acetyl-CoA): "Through the synthesis of the Kreb's Cycle this begins chemical reactions that creates usable energy from fat protein and carbohydrates. These reactions between pyruvate and acetyl-CoA to create CO2 [sic] water heat and ATP (energy) . CO2 is exhailed [sic] through respiration water is lost through urination and prespiration [sic] and heat is used to maintain proper body temperature." Other responses traced matter more superficially at the cellular level, briefly describing the correct molecular process but not mentioning individual molecules: "From the process of working out and dieting, the individual would break down fat cells and release carbon into the air as they exhaled. Other sugar molecules and fat molecules would be transformed into energy all equating to the 15 lbs [sic] lost."

The 9 total six-category responses contained ideas across scales as well: organismal ideas of *Exhalation*, *Excretion*, and *How to Lose Weight* occurred in all responses, while cellular-level ideas about *Correct Molecular Products* and *Matter Converted to Energy* occurred in 8 and 9 of these responses, respectively. Surprisingly, despite containing the maximum number of ideas possible, these nine responses appeared to focus on the more superficial level of explanation. These responses mentioned organismal-level physiological substances rather than cellular-level mechanistic intermediates: "In dieting, my friend would take in less calories than they will consume and their body will then use fat reserves to make ATP for energy. By the process of oxidation, it will produce CO2, [sic] water, and heat from the fat storage. Excreting CO2 by breathing, water as urine, and excreting heat will contribute to the 15 pounds of weight lost by my friend." It is interesting to note this vagueness was not observed to as large an extent in responses containing 5 ideas. This may be due to the high percentage of six-category responses (90%) compared to five-category responses (56%) that contained *Matter Converted to Energy* ideas. The high occurrence of this idea may be a result of the vague language students used in responses in this category.

In summary, we found that five-category responses were more detailed in their description of specific molecular details about fat conversion (i.e., the cellular level) than were six-category responses. Conversely, six-category responses seemed to focus at the physiological/organismal level of description, potentially due to the high percentage of responses containing the idea of *Matter Converted to Energy*. It was interesting for us to note

that, despite containing the most ideas, these responses did not provide more normative descriptions than responses containing fewer ideas.

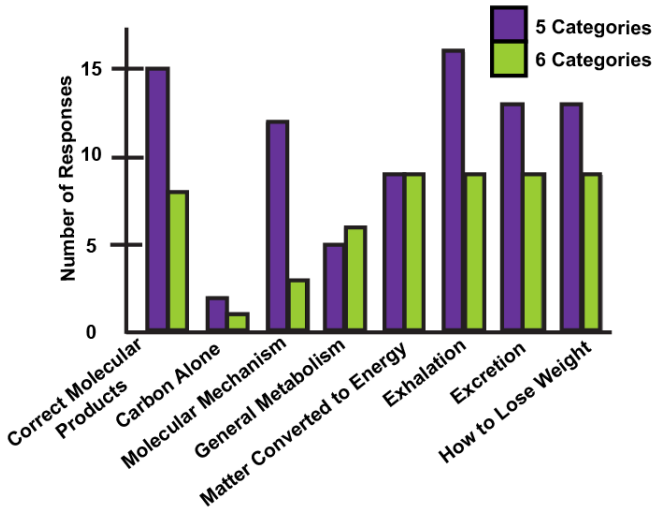

Figure S1: Five- and six-category contain high occurrences of both organismal- and cellular-level ideas. The graph above shows that ideas about *Exhalation* and *Correct Products* are the most commonly occurring ideas in five-category responses, while *Matter Converted to Energy, Exhalation, Excretion* and *How to Lose Weight* are the most commonly occurring ideas in six-category responses. Interestingly, we found more detailed descriptions of molecular mechanisms (i.e., key intermediates) in the five- rather than in the six-category responses.