Supplemental Material

CBE—Life Sciences Education

Offerdahl ***et al.***

Supplementary materials

Table S1: Representative examples of empirical and/or theoretical work in support of the proposed critical components of formative assessment.

Critical Component	Description	Representative Examples
Learning Outcomes	Clear criteria for success are identified.	Rust, C., Price, M., & O'Donovan, B. (2003). Improving students' learning by developing their understanding of assessment criteria and processes. *Assessment & Evaluation in Higher Education*, *28*(2), 147-164. Norton, L. (2004). Using assessment criteria as learning criteria: a case study in psychology. *Assessment & Evaluation in Higher Education*, *29*(6), 687-702. Handley, K., &Williams, L. (2011). From copying to learning: Using exemplars to engage students with assessment criteria and feedback. *Assessment & Evaluation in Higher Education*, *36*(1), 95–108.
Formative assessment prompts	Mechanisms for eliciting the range and extent of students' understanding are employed.	Tsai, C. C., & Huang, C. M. (2002). Exploring students' cognitive structures in learning science: a review of relevant methods. *Journal of biological Education*, *36*(4), 163-169. Furtak, E. M., & Ruiz - Primo, M. A. (2008). Making students' thinking explicit in writing and discussion: An analysis of formative assessment prompts. *Science Education*, *92*(5), 799-824.
Evidence of student understanding	Range and extent of student understanding is made explicit to teacher and student.	Ruiz-Primo, M. A., & Furtak, E. M. (2007). Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry. *Journal of research in science teaching*, *44*(1), 57-84. Offerdahl, E. G., & Montplaisir, L. (2014). Studentgenerated reading questions: Diagnosing student thinking with diverse formative assessments. *Biochemistry and*

		Molecular Biology Education, *42*(1), 29-38.
Feedback	Acomparison of the learner's current state with the criteria for success is used to generate timely, relevant, and actionable feedback.	Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological bulletin*, *119*(2), 254. Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, *77*(1), 81-112.
Skills for self-regulated learning	Students know how toidentify personal strengths/weaknesses relevant to instructional task, and create and monitor a plan for completing a learningtask.	Zimmerman, B. J., & Schunk, D. H. (Eds.). (2012). *Self-regulated learning and academic achievement: Theory, research, and practice*. Springer Science & Business Media. Hudesman, J., Crosby, S., Flugman, B., Issac, S., Everson, H., & Clay, D. B. (2013). Using formative assessment and metacognition to improve student achievement. *Journal of Developmental Education*, *37*(1), 2.
Personal pedagogical content knowledge(PCK)	Instructorspossess discipline-specific andpedagogicalknowledge for designing and reflecting on instruction of particular topics.	Tomanek, D., Talanquer, V., & Novodvorsky, I. (2008). What do science teachers consider when selecting formative assessment tasks?. *Journal of Research in Science Teaching*, *45*(10), 1113-1130. Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In *Re-examining pedagogical content knowledge in science education* (pp. 38-52). Routledge. Haug, B. S., & Ødegaard, M. (2015). Formative assessment and teachers' sensitivity to student responses. *International Journal of Science Education*, *37*(4), 629-654. Auerbach, A. J., Higgins, M., Brickman, P., & Andrews, T. C. (2018). Teacher Knowledge for Active-Learning Instruction: Expert–Novice Comparison Reveals Differences. *CBE-Life Sciences Education*, *17*(1), ar12.

Prior Knowledge	Students' prior knowledge is activated and interactswith how they learn information.	Heit, E. (1994). Models of the effects of prior knowledge on category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(6), 1264. National Research Council. (2000). *How people learn: Brain, mind, experience, and school: Expanded edition*. National Academies Press. Shapiro, A. M. (2004). How including prior knowledge as a subject variable may change outcomes of learning research. *American Educational Research Journal*, *41*(1), 159-189.
Reveal student understanding	The student(s) willingly respond to the formative assessment prompt appropriately.	Turner, G., & Gibbs, G. (2010). Are assessment environments gendered? An analysis of the learning responses of male and female students to different assessment environments. *Assessment & Evaluation in Higher Education*, *35*, 687–698. Havnes, A., Smith, K., Dysthe, O., & Ludvigsen, K. (2012). Formative assessment and feedback: Making learning visible. *Studies in Educational Evaluation*, *38*(1), 21-27. Winstone, N. E., Nash, R. A., Parker, M., & Rowntree, J. (2017). Supporting learners' agentic engagement with feedback: a systematic review and a taxonomy of recipience processes. *Educational Psychologist*, *52*(1), 17-37.
Personal pedagogical knowledge and skills (PCK&S)	The instructor uses particular discipline-specific knowledge and pedagogical skills to diagnose learning of a particular topic and provide feedback in a particular way to particular students.	Levin, D. M., Hammer, D., & Coffey, J. E. (2009). Novice teachers' attention to student thinking. *Journal of Teacher Education*, *60*(2), 142-154. Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice?. *Journal of Research in Science Teaching*, *50*(2), 189-208. Gess-Newsome, J. (2015). A model of teacher

		professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In *Re-examining pedagogical content knowledge in science education* (pp. 38-52). Routledge.
Diagnosis of in-progress learning	The instructor and/or student uses FA prompt and learning outcome to diagnose learner's current state.	Bischoff, P. J. (2006). The role of knowledge structures in the ability of preservice elementary teachers to diagnose a child's understanding of molecular kinetics. *Science Education*, *90*(5), 936-951. Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice?. *Journal of Research in Science Teaching*, *50*(2), 189-208.
Generate feedback	The instructor and/or student generate(s) feedback about learner's current state.	Bing-You, R. G., Paterson, J., & Levine, M. A. (1997). Feedback falling on deaf ears: Residents' receptivity to feedback tempered by sender credibility. *Medical Teacher*, *19*, 40–44. Nicol, D., Thomson, A., & Breslin, C. (2014). Rethinking feedback practices in higher education: a peer review perspective. *Assessment & Evaluation in Higher Education*, *39*(1), 102-122.
Recognize and respond to feedback	The student recognizes and acts on feedback to shape learning	Price, M., Handley, K., & Millar, J. (2011). Feedback: Focusing attention on engagement. *Studies in Higher Education*, *36*(8), 879-896. Orsmond, P., & Merry, S. (2013). The importance of self-assessment in students' use of tutors' feedback: A qualitative study of high and non-high achieving biology undergraduates. *Assessment & Evaluation in Higher Education*, *38*(6), 737-753. Ludvigsen, K., Krumsvik, R., & Furnes, B. (2015). Creating formative feedback spaces in large lectures. *Computers & Education*, *88*, 48-63.