

# Formative Assessment Practices in High School Classrooms - Experiences of a High School Teacher Teaching Engineering Design Curriculum

Assad Iqbal  
Engineering Education Department  
The Ohio State University  
Columbus, OH, USA  
[iqbal.111@osu.edu](mailto:iqbal.111@osu.edu)

Adam Carberry  
Engineering Education Department  
The Ohio State University  
Columbus, OH, USA  
[carberry.22@osu.edu](mailto:carberry.22@osu.edu)

Medha Dalal  
The Polytechnic School  
Arizona State University  
Mesa, AZ, USA  
[medha.dalal@asu.edu](mailto:medha.dalal@asu.edu)

**Abstract** – *This work-in-progress research explores the practice of formative assessments (FA) in the form of informal FA conversations by a high school teacher teaching engineering design curriculum in an all-girls high school in the US southwest. An observation protocol informed by the Eliciting, Students' response, Recognition, and Use (ESRU) model and Formative Assessment Cycle was developed and testing to capture informal FA practices in an authentic setting using classroom observations. The teacher observed in this study had no explicit awareness that her practices were being observed. Initial observations show a frequent utilization of informal FA practices associated with eliciting, recognizing, and using student responses to connect to learning goals in the form of FA conversations. These practices did not include clarifying expectations or sharing learning goals. Initial observations also show that the teacher frequently uses these practices to introduce new topics instead of starting such engagements to assess concepts that have already been delivered. Implications and future directions will focus on understanding how these inquisitive, informal FA practices can be used to deliver new concepts and improve student learning.*

**Keywords** — *formative assessment, teacher experiences, pre-college engineering education, learning goals, engineering design.*

## I. INTRODUCTION

Research has established the forward (potentiating learning of new information) and backward (retention of already learnt information) effects [1, 2] of academic testing in laboratory and classroom settings across various subject areas, academic levels, and genders [3]. High test anxiety associated with high stakes testing [4] undermines positive effects towards student learning [4-6]. These findings make formative assessments (FA) a favorable choice to leverage the positive effects of testing. Despite varying definitions, approaches, and ideas [8], formative assessment (FA) is a form of testing that serves the fundamental purpose of providing instructional feedback [9, 10] and facilitates students' learning during the teaching and learning process [11, 12].

FA has been widely recognized and proposed as one of the core elements to enhance the effectiveness of teaching and learning [13,14]. In process terms, FA is defined as a learner-centered approach involving continuous collection of information about students' learning and using that

information to make decisions and to determine teaching adjustments to meet student needs [15]. Extensive empirical and theoretical research exists supporting the positive effects of FA practices in its various forms (e.g., homework, quizzes, projects, presentations, discussions etc.), contexts (online, face-to-face, hybrid), and within different subject areas [9, 16-19]. Research shows that FA helps teachers assess their instructional effectiveness, aids students in identifying and addressing misconceptions [18, 20], and builds teacher-student relationships [21] to enhance students' learning achievement [22-24], engagement, and satisfaction levels [19].

The use of FA has been on the rise in classroom practice [25]. However, increased use has not resulted in widespread adoption of FA as a teaching approach [26, 27]. Teachers frequently encounter challenges when attempting to translate FA theory into their teaching practices [28]. This lack of understanding leads most teachers to adopt formative assessments as a set of activities without considering students' autonomy [29, 30]. It is therefore necessary to conduct more empirical research to examine the nature of teachers' FA practices, analyze and elucidate the FA process in the classroom, and ascertain the extent of student involvement in this process [31, 32]. Wiliam [33] contends that more descriptive research is necessary to understand the specific actions teachers undertake in their FA practices in the classroom before studying the effects of FA on student learning. This study aims to provide additional empirical evidence by investigating teacher FA practices in the classroom.

## II. THEORETICAL FRAMING

Numerous theories and frameworks exist that describe and define formative assessment (FA) [34-37]. These frameworks share certain common features, but each also emphasizes its own distinct perspective on the process of formative assessment (FA). This study uses the Elicit, Student response, Recognition, Use (ESRU) framework [35] while incorporating the first phase (clarifying expectations) of the formal Formative Assessment (FA) Cycle [37]. The chosen framing provides a foundation for an in-depth study of formative assessment practices by a high school teacher, teaching engineering design curriculum at an all-girls high school in the US southwest.

According to the ESRU framework [35], formative assessment can take the form of an informal student-teacher interaction (referred to as informal formative assessment conversation), which allows teacher to gather information about students' level of understanding, mental models, strategies, language, and communication skills to guide instruction. The teacher asks a question (elicit), and students respond to the question. The teacher then recognizes students' responses and compares them to the expected responses (implicit learning goals) to identify the next course of action (use) to move students towards the learning goals. The ESRU model proposes examining informal formative assessment conversations in relation to the three interconnected facets of science education i.e., epistemic, conceptual, and social. Epistemic structures refer to knowledge frameworks involving rules and criteria (e.g., experiments, hypotheses, and explanations). Conceptual structures involve deep understanding of concepts. Social processes refer to students' scientific communications related to scientific inquiry. This study aims to identify if and how ESRU framework is used in a high school engineering classroom. This study also tries to identify if the teacher is sharing the learning goals with the students i.e., clarifying expectations prior to eliciting students' responses, recognizing these responses, and using these responses to achieve the learning goals.

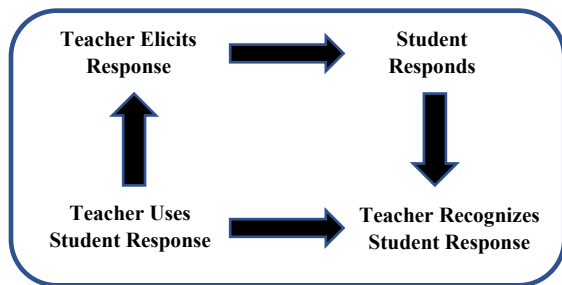


Figure 1: The ESRU Model of Informal Formative Assessment [35]

### III. METHODS

#### *Research Team Positionality and Epistemologies*

This study is influenced by the research team's position and epistemologies toward FA practices. We believe that identification of clarified expectations or learning goals will add value to the understanding of teachers' FA practices because it will enable the researcher to identify the extent to which the teacher can guide informal FA conversations towards delivering learning goals.

#### *Context of the study*

This study was undertaken within the context of a larger project, Engineering for Us All (E4USA) funded by

National Science Foundation. The objective of the E4USA project is to develop an inclusive engineering design curriculum and demystify the field of engineering for high school students and teachers. The course uses a series of collaborative projects to establish a strong foundation of engineering design and professional skills for all students regardless of their interest in engineering. For more information on E4USA, visit <https://e4usa.org/>.

#### *Data Collection and Analysis*

Data was collected using a modified version of the Informal Formative Assessment Conversations protocol [35] within an all-girls classroom taught by a female teacher originally teaching environmental science. Observations from eight class sessions are included in this analysis. Observations were collected by the researcher in-person during the class sessions. A deductive coding analysis approach was employed to code and analyze the informal formative assessment conversations data [38]. Codes and categories given in the Informal Formative Assessment Conversation protocol [35] were used as priori. Slight modifications to the protocol were made to capture if the teacher explicitly clarified expectations (learning goals) prior to starting the class session or during the conversations. The collected data was read and verified for correct mapping against the categories and codes provided in the protocol.

### IV. PRELIMINARY RESULTS

#### *Informal Formative Assessment Conversations*

Preliminary results demonstrate that informal formative assessment conversations were used in seven of eight class sessions observed. Multiple informal formative assessment conversations were observed in 4 class sessions, while the remaining three class sessions included only one formative assessment conversation each (Table 1).

Table 1: Formative Assessment Conversations Observed

| Class session | No. of FA Conversations Observed |
|---------------|----------------------------------|
| Session 1     | 3                                |
| Session 2     | 0                                |
| Session 3     | 2                                |
| Session 4     | 2                                |
| Session 5     | 2                                |
| Session 6     | 1                                |
| Session 7     | 1                                |
| Session 8     | 1                                |

All formative assessment conversations observed in the class sessions followed the complete Elicit, Student response, Recognition and Use (ESRU) cycles. The teacher always asked a question situated in epistemic or conceptual (or both) frameworks to elicit students' knowledge about a concept, recognize students' responses (e.g., revoice, rephrase, and elaborate), and use students' responses to explain, elaborate, and clarify concepts (the ultimate learning goals). A sample of the teacher-student dialogue identified as informal formative assessment conversation is given in Figure 2.

It is worth mentioning here that the teacher who was teaching this class was not made aware that the observer was trying to identify the practice of formal or informal formative assessment conversations in the class.

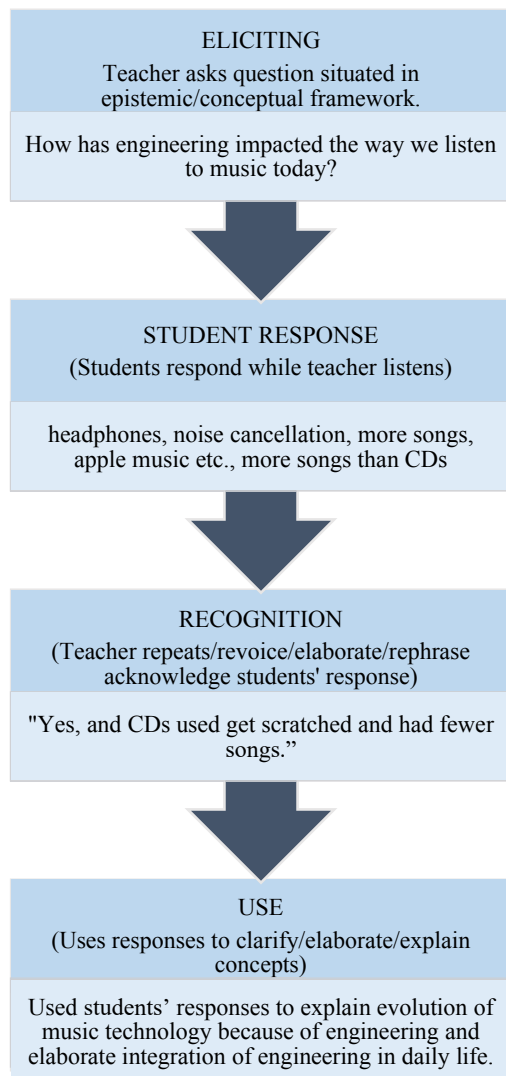


Figure 2: ESRU Cycle observed in a sample conversation.

### Eliciting Strategies

Further analysis of the conversations showed that in most assessment conversations, the teacher's eliciting strategy focused on questions and statements which were epistemic in nature. Overall, questions and statements related to epistemic dimension were used in 9 of 12 conversations observed during the 8 class sessions. Eliciting questions related to the epistemic dimension were most frequently about "*checking students' comprehension*". Asking students to "*compare/contrast observation data, procedures, and/or ideas*" was the second most frequently asked question for eliciting students' knowledge and understanding within the epistemic dimension. Eliciting questions asking students to "*provide evidence & examples,*" "*relate evidence & explanations,*" and "*make predictions or provide hypotheses*" were least frequently used eliciting questions related to the epistemic dimension (Table 2).

The teacher less frequently (in only 3 of 12 conversations) used some eliciting questions and statements in the conceptual domain. The most frequently used conceptual domain question asked students to "*apply, relate, compare, and contrast concepts.*" Students were asked to "*compare and contrast others' ideas*", and "*provide potential or actual definitions*" second and third in terms of frequency (Table 2).

Table 2: Strategies Used for Eliciting

| Eliciting Strategy                                    | Freq. |
|-------------------------------------------------------|-------|
| <u>Epistemic Dimension</u>                            |       |
| Check students' comprehension                         | 07    |
| Compare/contrast observations data, procedures, ideas | 02    |
| Provide evidence & examples                           | 01    |
| Relate evidence & explanations                        | 01    |
| Make predictions/provide hypotheses                   | 01    |
| <u>Conceptual Dimension</u>                           |       |
| Apply, relate, compare, contrast concepts             | 03    |
| Compare, contrast others' ideas                       | 02    |
| Provide potential or actual definition                | 01    |

### Recognizing Strategies

The most common strategy to recognize students' responses to eliciting questions in both the epistemic and conceptual dimensions was to repeat or rephrase students' responses and revoice their words to acknowledge and incorporate their contributions into the learning process. Clarifying and elaborating concepts based on students' responses and taking votes to acknowledge students' ideas were the second and third most frequently used recognition

strategies. There was also one occurrence where the teacher captured students' responses and explanations and displayed them for everyone to see (Table 3).

Table 3: Strategies Used for Recognizing

| Recognizing Strategies                                                                                                                                      | Freq. |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Repeats/paraphrases students' words                                                                                                                         | 6     |
| Revoices students' words (incorporates students' contributions into the class conversation, summarizes what student said, acknowledge student contribution) | 6     |
| Clarifies/Elaborates based on students' responses                                                                                                           | 4     |
| Takes votes to acknowledge different students' ideas                                                                                                        | 3     |
| Captures/displays students' responses/explanations                                                                                                          | 1     |

### Use Strategies

All formative assessment conversations were characterized by all four components of the ESRU cycle and after eliciting and recognizing students' response. The teacher used those responses as the desirable next step in formative assessments, i.e., using gathered information to provide feedback. The strategy was most frequently characterized by providing helpful descriptive feedback, promoting sense-making, and helping students to relate evidence to explanations (Table 40). The teacher was also observed helping students elaborate their thinking by using follow-up (why and how) questions.

Table 4: Use Strategies

| Use Strategy                                                                        | Freq. |
|-------------------------------------------------------------------------------------|-------|
| Provides descriptive/helpful feedback                                               | 7     |
| Promotes making sense                                                               | 4     |
| Helps relate evidence to explanations                                               | 4     |
| Promotes students' thinking by asking them to elaborate their responses (why, how?) | 3     |
| Makes connections to previous learning                                              | 1     |
| Promotes debating and discussion among students' ideas/conceptions                  | 1     |
| Helps students achieve consensus                                                    | 1     |

## V. DISCUSSION & FUTURE WORK

PRELIMINARY analysis of observations showed a frequent use of formative assessment conversations with complete ESRU cycles in class discussions. This emergent finding is indicative of teachers' informal formative assessment practices in the classroom [10, 35]. The frequency of completed ESRU cycles also indicates the extent to which information gathered from students was used in ways to help students' learning. It is encouraging to note (Tables 1 – 4) that the teacher not only used more

frequent informal formative assessment conversations, but also used a variety of strategies (questions and statements) in all components of the ESRU cycles. One interesting aspect of the informal formative assessment conversations used by this teacher was the use of these practices to introduce new topics. For example, to teach students the significance of "defining the problem" in the context of engineering design process, the teacher started in informal FA conversation with an eliciting question, "*why according to Einstein it is important to take more time to define the problem than to solve it?*". Similarly, in another class session, the teacher started the conversation by asking the students (eliciting), "*How do you listen to music today?*". The conversation followed the ESRU cycle to teach students about how music has evolved over time because of engineering and how engineering is everywhere in our daily life. These assessment conversations seemed to spark students' interest in the topic and led them to participate in the conversations to learn new information. Further exploration of this unique aspect is warranted.

Research argues that the diversity and relevance of eliciting, recognizing, and using strategies determines the quality of the informal formative assessment practices [35]. Using a combination of different types of questions (e.g., checking students' comprehension followed by asking them to provide evidence and examples) to make predictions or build a hypothesis about a phenomenon makes these conversations more productive in terms of the quality of students' learning. Future research will aim to further our understanding of teacher use of informal formative assessment practices. These efforts will be paired with observations of how or if teachers share the learning goals or clarify lesson expectations at the start of class before starting formative assessment conversations. This critical first step in the formative assessment cycle was missing from all observations made of this teacher warranting further examination.

The researchers aim to build on this work in progress to include teachers' experiences at other schools associated with E4USA project. Expanding the research to include observations from more classrooms observed under the umbrella of E4USA may also help researchers find more insights into the experiences of teachers practicing informal formative assessments in their classroom while teaching the same curriculum. This research has implications for pre-college engineering education. As pre-college engineering education continues to grow, equipping teachers with essential pedagogical tools such ESRU could help improve students' learning.



## REFERENCES

- [1] Adesope, O. O., Trevisan, D. A., & Sundararajan, N. (2017). Rethinking the use of tests: A meta-analysis of practice testing. *Review of Educational Research*, 87, 659–701. <http://dx.doi.org/10.3102/0034654316689306>
- [2] Chan, J. C., Meissner, C. A., & Davis, S. D. (2018). Retrieval potentiates new learning: A theoretical and meta-analytic review. *Psychological Bulletin*, 144, 1111–1146. <http://dx.doi.org/10.1037/bul0000166>
- [3] Yang, C., Luo, L., Vadillo, M. A., Yu, R., & Shanks, D. R. (2021). Testing (quizzing) boosts classroom learning: A systematic and meta-analytic review. *Psychological Bulletin*.
- [4] Khanna, M. M. (2015). Ungraded pop quizzes: Test-enhanced learning without all the anxiety. *Teaching of Psychology*, 42(2), 174–178.
- [5] Tobias, S. (1985). Test anxiety: Interference, defective skills, and cognitive capacity. *Educational Psychologist*, 20(3), 135–142.
- [6] Tse, C. S., & Pu, X. (2012). The effectiveness of test-enhanced learning depends on trait test anxiety and working-memory capacity. *Journal of Experimental Psychology: Applied*, 18(3), 253.
- [7] Brookhart, S. M. (2018). Summative and formative feedback. In A. Lipnevich & J. Smith (Eds.), *The Cambridge handbook of instructional feedback* (pp. 52–78). Cambridge, UK: Cambridge University Press. doi:10.1017/9781316832134.005
- [8] Wiliam, D. (2018). Feedback: At the heart of – But definitely not all of – Formative assessment. In A. Lipnevich & J. Smith (Eds.), *The Cambridge handbook of instructional feedback* (pp. 3–28). Cambridge, UK: Cambridge University Press. doi:10.1017/9781316832134.003
- [9] Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, 21, 5–31. doi:10.1007/s11092-008-9068-5
- [10] Ruiz-Primo, M. A., & Brookhart, S. M. (2018). Using feedback to improve learning. London, UK: Routledge. Sadler, D. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18, 119–144. doi:10.1007/BF00117714
- [11] Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1), 81–112. doi:10.3102/003465430298487
- [12] Sadler, D. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18, 119–144. doi:10.1007/BF00117714
- [13] Black, P., & Wiliam, D. (2018). Classroom assessment and pedagogy. *Assessment in Education: Principles, Policy & Practice*, 25(6), 551–575. <https://doi.org/10.1080/0969594X.2018.1441807>
- [14] OECD [The Organization for Economic Cooperation and Development]. (2005). *Formative assessment. Improving learning in secondary classrooms* [Adobe Digital Editions version]. Retrieved on 19 April 2023 from [https://www.oecd-ilibrary.org/education/formative-assessment\\_9789264007413-en](https://www.oecd-ilibrary.org/education/formative-assessment_9789264007413-en)
- [15] Pat-El, R. J., Tillema, H., Segers, M., & Vedder, P. (2015). Multilevel predictors of differing perceptions of Assessment for Learning practices between teachers and students. *Assessment in Education: Principles, Policy & Practice*, 22(2), 282–298. <https://doi.org/10.1080/0969594X.2014.975675>
- [16] Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: principles, policy & practice*, 5(1), 7–74.
- [17] Cummings, A. T. (2020). Correlation of Student Participation in Practice Exams and Actual Exam Performance.
- [18] O'Connell, R. (2015). Tests given throughout a course as formative assessment can improve student learning. In *ASEE Zone III Conference (USA)*, Washington DC: American Society for Engineering Education.
- [19] Pick, L., & Cole, J. (2021, March). "Building Students Agency through Online Formative Quizzes. In *The 17th CDIO International Conference*.
- [20] Guskey, T. R. (1996). *Implementing mastery learning* (2nd ed.). Belmont, CA: Wadsworth
- [21] Popham, J. W. (2011). *Transformative assessment in action: An inside look at applying the process*. Alexandria, VA: ASCD
- [22] Fiel, R. L., & Okey, J. R. (1974). The effects of formative evaluation and remediation on mastery of intellectual skills. *The Journal of Educational Research*, 68, 253–255.
- [23] Popham, J. W. (2008). *Transformative assessment*. Alexandria, VA: ASCD.
- [24] Block, H., & Burns, R. (1976). A meta-analysis of mastery learning through formative assessment. *Review of Research in Education*, 4, 3–49.
- [25] Carless, D. (2017). Scaling up assessment for learning: Progress and prospects. In D. Carless, S. M. Bridges, C. K. Y. Chan, & R. Glofcheski (Eds.), *Scaling up assessment for learning in higher education* (vol. 5, pp. 3–17). Singapore: Springer. <https://doi.org/10.1007/978-981-10-3045-1>
- [26] Deneen, C. C., Fulmer, G. W., Brown, G. T. L., Tan, K., Leong, W. S., & Tay, H. Y. (2019). Value, practice and proficiency: Teachers' complex relationship with assessment for learning. *Teaching and Teacher Education*, 80, 39–47. <https://doi.org/10.1016/j.tate.2018.12.022>
- [27] Kippers, W. B., Wolterinck, C. H. D., Schildkamp, K., Poortman, C. L., & Visscher, A. J. (2018). Teachers' views on the use of assessment for learning and data-based decision making in classroom practice. *Teaching and Teacher Education*, 75(October), 199–213. <https://doi.org/10.1016/j.tate.2018.06.015>
- [28] Robinson, J., Myran, S., Strauss, R., & Reed, W. (2014). The impact of an alternative professional development model on teacher practices in formative assessment and student learning. *Teacher Development*, 18(2), 141–162. <https://doi.org/10.1080/13664530.2014.900516>
- [29] Marshall, B., & Drummond, M. (2006). How teachers engage with assessment for learning: Lessons from the classroom. *Research Papers in Education*, 21(2), 133–149. <https://doi.org/10.1080/02671520600615638>
- [30] Birenbaum, M. (2014). Conceptualizing assessment culture in school (2014). In C. Wyatt-Smith, V. Klenowski, & P. Colbert (Eds.), *Designing assessment for quality learning* (vol. 1, pp. 285–302). Dordrecht: Springer. <https://doi.org/10.1007/978-94-007-5902-2>
- [31] Andersson, C., & Palm, T. (2018). Reasons for teachers' successful development of a formative assessment practice through professional development – A motivation perspective. *Assessment in Education: Principles, Policy & Practice*, 25(6), 576–597. <https://doi.org/10.1016/j.learninstruc.2016.12.006>
- [32] Antoniou, J., & James, M. (2014). Exploring formative assessment in primary school classrooms: Developing a framework of actions and strategies. *Educational Assessment, Evaluation and Accountability*, 26(2), 153–176. <https://doi.org/10.1007/s11092-013-9188-4>
- [33] Wiliam, D. (2018). *Formative assessment: Confusions, clarifications & prospects for consensus* [Seminar presentation]. February 28. United Kingdom: Oxford [https://www.dylanwiliam.org/Dylan\\_Wiliams\\_website/Presentations.html](https://www.dylanwiliam.org/Dylan_Wiliams_website/Presentations.html)
- [34] Bennett, R. E. (2011). Formative assessment: A critical review. *Assessment in Education: Principles, Policy & Practice*, 18(1), 5–25. <https://doi.org/10.1080/0969594X.2010.513678>
- [35] Ruiz-Primo, M. A., & Furtak, E. M. (2006). Informal formative assessment and scientific inquiry: Exploring teachers' practices and student learning. *Educational Assessment*, 11(3-4), 205–235. <https://doi.org/10.1080/10627197.2006.9652991>
- [36] Wiliam, D. (2011). What is assessment for learning? *Studies in Educational Evaluation*, 37, 3–14. <https://doi.org/10.1016/j.stueduc.2011.03.001>
- [37] Gulikers, J., & Baartman, L. (2016). Teachers' formative assessment practices in the classroom: A literature review. In *Paper presented at the Competence Conference*
- [38] Saldña, J. (2009). *The coding manual for qualitative researchers*. London, UK: SAGE Publications Ltd