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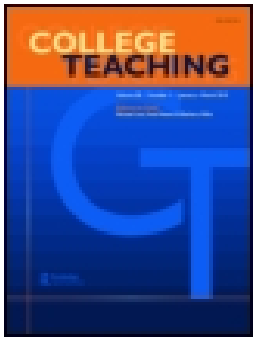
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“Acing” the Feedback: The A²CE Framework for Generating Impactful Interactions with Students about Their Approaches to Learning

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ABSTRACT

To help students become better learners, educators need to be able to provide feedback to students on their learning processes. However, this can be challenging for educators due to the customized nature of such feedback. To that end, we have created and evaluated the Acknowledge, Affirm, Challenge, and Encourage (A²CE) framework as a practical and scalable way to provide formative feedback for engineering students. The A²CE framework was: 1) developed through a research project focused on developing metacognitive skills in engineering students, and 2) evaluated for functionality in a workshop setting where we taught educators how to use the A²CE framework. Within the workshop, we collected participants' feedback on the framework in the form of open-ended surveys. Analysis of responses revealed that workshop participants believed the A²CE framework was useful as a method for having caring conversations with students about their learning, while giving constructive feedback that students can use to improve their learning in and out of the classroom; prior to the workshop, participants indicated a need for more support in having meaningful conversations with their students about learning processes. We conclude that the A²CE framework is an accessible tool educators can leverage to help students improve as learners.

KEYWORDS

Faculty development;
feedback; feedback template;
metacognition

Introduction

To help students become better learners, educators need to talk openly with students about learning. Specifically, because students are not always accurately self-aware of their own learning habits, educators can focus on helping students develop their metacognitive skills. However, helping students means having a way to provide feedback on how their development as learners is progressing, which is something not all engineering educators are prepared for or even trained to do. To close this gap, we propose the Acknowledge, Affirm, Challenge, and Encourage, or A²CE, a framework for providing students feedback as they develop metacognitive skills. Our approach is novel because it addresses both theory and practice. The A²CE framework itself is grounded in literature on educational theory, teaching practice, and guiding behavioral change (e.g., Dweck, 2008; Miller & Rose, 2009; Moore et al., 2016; Nicol & Macfarlane-Dick, 2006; Rollnick & Allison, 2004). The A²CE framework also emerged from educator feedback on an iterative

deployment of an intervention to promote metacognitive skills in engineering students that required giving students feedback on their self-assessment of learning (Cunningham et al., 2017). Herein, we describe the A²CE framework and provide evaluation data in the form of feedback from educators on the functionality of the A²CE framework as a teaching tool. As outlined by multiple research studies, a focus on disseminating teaching interventions and their efficacy in improving student outcomes alone is not enough to ensure that interventions are adopted, and educational change occurs (Borrego et al., 2010, 2013). Therefore, herein we focus on understanding if and how the A²CE framework meets the needs of educators as a tool to provide effective metacognitive feedback, thus contributing to the goal of developing reflective teachers called out by Borrego and Henderson (2014). In the form of evaluation data, reactions from educators show that in practice, the A²CE framework approach is believed to be easy to use and applicable across multiple contexts.

The importance of teaching and learning metacognition for engineering students

Metacognitive development is relevant to all learners and ultimately enables students to know about and take responsibility for their thinking and learning (Ambrose et al., 2010; Pintrich, 2002). We argue that metacognitive development is particularly important within engineering education for two reasons: 1) engineering work relies heavily on problem-solving, and 2) engineering courses are concept-heavy and metacognitive skills are critical in developing conceptual understanding. The National Academy of Engineering report, *The Engineer of 2020*, defines a core aspect of engineering as problem-solving (National Academy of Engineering, 2004). Metacognition plays a pivotal role in solving complex, open-ended, or ill-structured problems (Jonassen, 2011). Metacognitively skilled learners are better able to recognize there is a problem, define and scope the problem, and develop a process for reaching a solution (Davidson et al., 1994). For example, Chi et al. (1989) found that students who engaged in self-explanations, and thus engaged in more self-monitoring activities, tended to be better problem solvers. Metacognition has also been identified as a skill set critical to developing conceptual knowledge and addressing misconceptions (King & Kitchener, 2004; Luque, 2003; Pintrich et al., 1993; Rittle-Johnson et al., 2001). Unfortunately, research in conceptual learning in engineering has shown that engineering students are graduating from undergraduate programs without understanding fundamental concepts in areas such as physics, electricity, statics, materials, and thermodynamics (Hestenes et al., 1992; Krause et al., 2009; Steif et al., 2010; Streveler et al., 2008) revealing a need to focus on developing metacognitive skills.

Because metacognitive skills are important in engineering, engineering educators must help students develop these skills. In fact, *Educating the Engineer of 2020* specifically called for the training of engineers as problem solvers and lifelong learners: “As well as delivering content, engineering schools must teach engineering students how to learn, and must play a continuing role along with professional organizations in facilitating lifelong learning...” (National Academy of Engineering, 2004, p. 55).

Fortunately, there is existing research on facilitating students’ metacognitive development. Veenman et al. (2006) specify the need for three items: explicit instruction, authentic practice, and feedback with further practice. In prior but related work, we designed student metacognition training modules (hereafter known as modules) (Grant Nos. 1433757

& 1433645) to embody the first two items situated within engineering courses (Cunningham et al., 2018). Though not the only approaches to developing metacognitive learners, they inform the work herein. The work presented herein addresses Veenman et al.’s (2006) third point of feedback with further practice. Thus, herein we focus in detail on describing the use of the A²CE framework to provide students feedback about their developing metacognitive skills and outcomes from a workshop teaching faculty to use this framework in their interactions with students.

Literature on giving feedback

While existing recommendations for giving feedback on course assignments do seek to prompt students to engage in deeper learning (Crouch & Mazer, n.d.), they do not generally lead to students thinking about their approaches to learning or changing those approaches to learning (see, e.g., Chapter 1 in Nilson, 2013). The types of feedback commonly given to students can be broadly categorized as formative or summative. Formative feedback is usually ungraded and often delivered informally through interactions during in-class activities. Its purpose is to point students toward improvement. It focuses on specific skills or understanding, and requires low effort, as it naturally occurs during learning activities. Davis (2016) and Fluckiger et al. (2010) provide examples of activities aimed toward formative feedback. In comparison, summative feedback is usually graded, is constructed outside of class, and is delivered formally. Its purpose is to judge students’ proficiency with course objectives, it is more broadly focused on a range of skills and knowledge, and requires more time and effort, as it is more complex and comprehensive (Crouch & Mazer, n.d.). At the high level, formative assessment has been found to be more effective in helping students develop deeper learning than summative feedback (Crouch & Mazer, n.d.).

Existing literature on feedback tends to focus on student learning. In fact, there are several summaries of feedback characteristics that support student learning, e.g., timeliness, goal-referenced, and personal (Crouch & Mazer, n.d.; Gibbs & Simpson, 2004; Glover & Brown, 2006; Nicol & Macfarlane-Dick, 2006; O’Neill, n.d.; Race, 2002; Wiggins, 2012). (A brief summary of these features is available on <https://skillful-learning.org/resources/>)

However, helping students learn content better is fundamentally different from helping students grow

as more skillful learners (Nilson, 2013; Schraw et al., 2006; Van Meter et al., 2016). They are not unrelated, but they are distinct. Learning content and improving content knowledge primarily involve cognitive processes directed at repairing gaps and knowledge deficiencies compared to demonstrable criteria. Becoming a more skillful learner, on the other hand, addresses habits of learning, which have been developed and reinforced over many years. These habits of learning are deeply ingrained and are often highly resistant to change. Therefore, growing as a skillful learner is inherently metacognitive and motivational. It requires awareness and regulation of how one processes information and the desire to pursue it. While formative feedback for improving student performance, mentioned previously, may be of some use when giving students feedback about their approaches to learning, it is inadequate to guide students toward awareness of their need to modify their habits of learning and the commitment to see these changes through.

Previous work and motivation for A²CE

The need for the A²CE feedback framework emerged from research associated with developing instructional modules to teach metacognition to undergraduate engineering students. Figure 1 provides an overview of our work that has the desired outcome of improved student metacognitive abilities.

To achieve this outcome, we designed a series of metacognition modules for use by students and instructors to develop students' metacognitive skills (Step 1 - complete). Student and instructor feedback led to iterative improvement into the Skillful Learning modules. During this feedback collection, instructors highlighted their need for help in providing students feedback on metacognition, leading to Step 2: the development of the A²CE framework (the focus of this manuscript). Importantly, we have engaged in a cycle of research-informed practice and practice-informed research with our work (Jamieson & Lohmann, 2009). Therefore, we give a brief

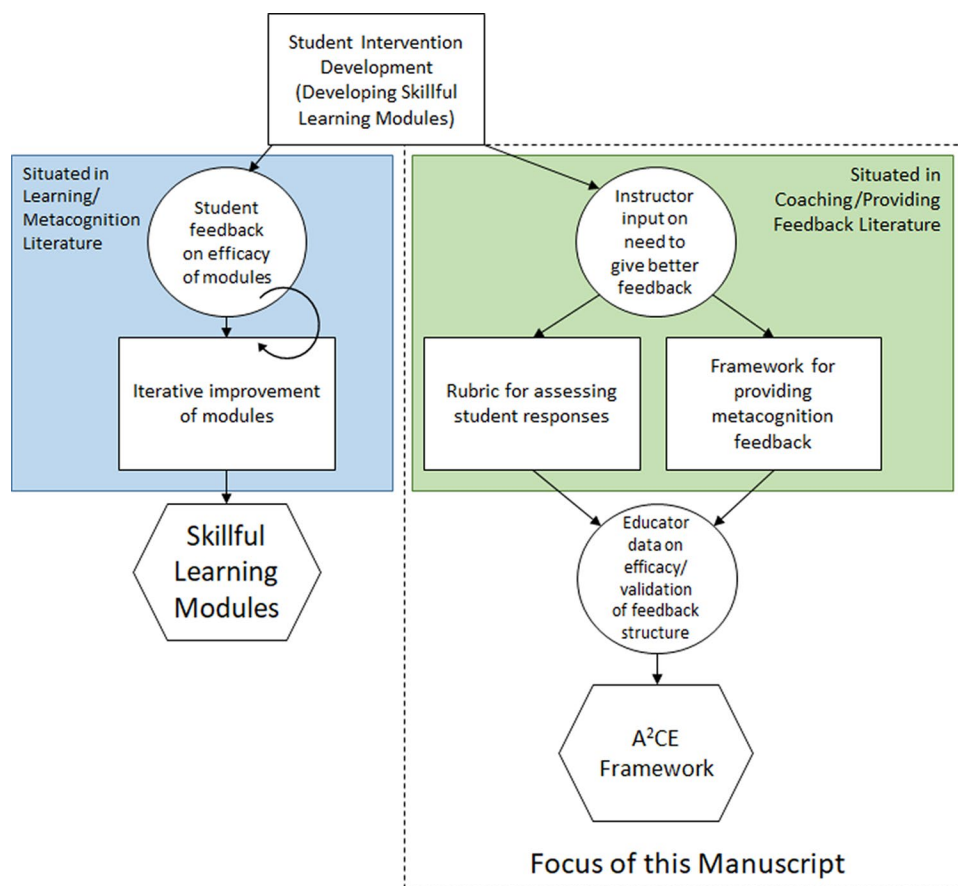


Figure 1. This process map for metacognition project shows how this work focuses on educators' reactions and perceptions of the A²CE feedback framework. Other work has looked at the efficacy of the modules in supporting students developing as more skillful learners.

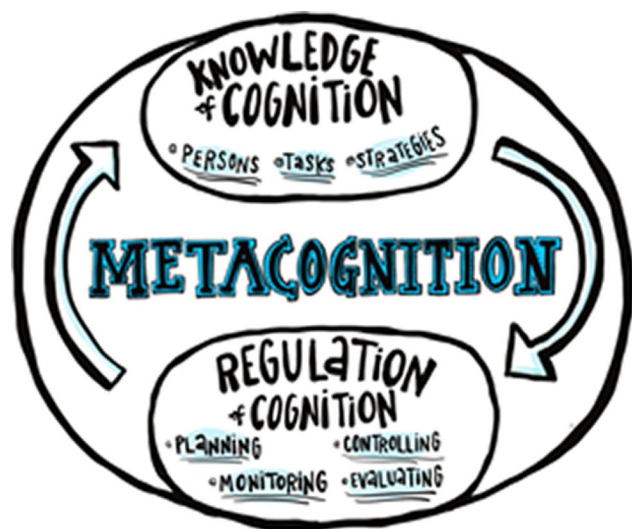


Figure 2. Our conceptual framework of metacognition encompasses the most commonly agreed upon elements categorized into knowledge and regulation of cognition (thinking processes). (Image retrieved from metacognition training videos made with prior NSF-funded project - Grant Nos. 1433757 & 1433645.)

overview of the metacognition theory and the modules we created and tested, drawing on this theory before introducing the A²CE framework.

Metacognition theory-informed skillful learning modules

Our Skillful Learning module design, grounded in theory on metacognition, was achieved through multiple rounds of testing. Our guiding conceptual framework, depicted in Figure 2, displays the two main components of metacognition: knowledge of cognition and regulation of cognition.

Knowledge of cognition includes knowledge of persons, knowledge of the task, and knowledge of strategies (Flavell, 1979; Tarricone, 2011). Regulation of cognition generally includes planning, monitoring, controlling, evaluating, or similar elements (Tarricone, 2011; Whitebread et al., 2007). These two components of metacognition interact and reinforce each other to a high degree (Tarricone, 2011), as emphasized with cyclical arrows in Figure 2. Regulation draws on and is informed by knowledge of cognition and knowledge of cognition is built, in part, through the practice of regulation of cognition.

Table 1 outlines how the modules fit in with different aspects of metacognition. Each module included pre-class, in-class, and post-class work associated with a video on each of the topics. Modules contained questions that asked students to self-evaluate to help students develop metacognitive skills.

Table 1. Module names and metacognitive focus. The modules walk students through key elements of metacognition.

Module Name	Metacognitive Focus
What is Metacognition and Why Should I Care?	Overview
Knowing About Thinking	Metacognitive Knowledge
Reflecting on Our Thinking	Metacognitive Evaluation
Planning for Our Thinking	Metacognitive Planning
Optimizing Our Thinking	Metacognitive Monitoring and Control
Thinking Back and Thinking Ahead	Personalized Summary & Transfer

Through implementing and evaluating these modules (Cunningham et al., 2015, 2017, 2018) and interviewing educators to ask about their willingness to use such modules (e.g., Williams et al., 2016; Figure 1), it became apparent that there was a need to better prepare educators to talk about metacognition and specifically to be able to provide students feedback on their self-assessments of learning skills. Thus, we created the A²CE framework.

The A²CE framework

The purpose of the A²CE framework is to enable instructors to provide feedback to students on their learning behaviors and is rooted in the practice of motivational interviewing for coaching. In this case, the educator is the coach, and the student is the coachee. The A²CE framework was designed to be practical and practice-based, adaptable to the variety of interactions educators have with students. After describing the individual elements, we offer a practical example of applying the A²CE framework to a written response from a student.

Theoretical grounding of the A²CE framework elements beyond metacognition theory

The A²CE feedback framework is grounded in the practice of motivational interviewing. Coaching psychologists and professional coaches use motivational interviewing as a practice to aid clients seeking to make behavioral changes in their personal or professional lives (Moore et al., 2016; Palmer & Whybrow, 2018). Within motivational interviewing, empathetic listening and questions are used to engage the coachee to build a trusting relationship, helping them feel understood and supporting their autonomy. Gentle and open-ended questions are used with empathetic listening to help coachees focus more clearly on their goals, evoke their internal motivation, and construct action plans (Moore et al., 2016; Rollnick & Allison, 2004). These strategies enable

the coach to come alongside coachees rather than overtly confront them, aiding their processing of ambivalence and internal discontinuities while supporting the development of their self-efficacy (i.e., their belief in their ability to enact and achieve the desired changes). This is gentle work, respecting the individual, and seeking to stay in step with their readiness to change, avoiding or mitigating resistance to change (Rollnick & Allison, 2004).

The construction of the A²CE framework embodies these dimensions in an accessible and practical form, easy to implement with students. We developed the A²CE framework for providing more constructive and productive feedback to students about their approaches to learning, creating opportunities for further interaction with students, and empowering them to improve self-assessment of their learning and learning processes. The elements are described in more detail in the next section and are illustrated with a practical example. Ultimately, the A²CE framework provides educators with a way of giving feedback to students on their learning behaviors that coaches students toward more skillful learning behaviors better aligned with their personal and professional goals.

The elements of A²CE

Acknowledging is a mindset and means recognizing that our knowledge of the student and their situation is limited. We need to avoid jumping to conclusions or making assumptions about the student. It sets us up to understand the student and their context and explore a student's approaches to learning with them, and even help the student discover their ineffective approaches. This is important for exploring a student's readiness to change, ambivalence to making changes to their learning behaviors, and constructively responding to a student's resistance to potential changes, the key concepts behind motivational interviewing. Instead of thinking, e.g., "this student is just lazy," we can view this as an opportunity to get to know the student better and help them see their reality more clearly. This positive mindset is the foundation for then Affirming, Challenging, and Encouraging the student with our feedback.

Affirming means to sincerely praise some element of the student's approach, even honest effort with an ineffective learning strategy. It should be real, genuine, and directed at the behavior. Affirming can also be seen as empathetic listening, where the educator restates what they heard the student say, which enables the educator to check their understanding (and allows students to correct misunderstandings) and helps the

student feel heard. For example, in meeting with the student at their request after the exam, we could open our response with, "I see you care about how you are doing in this class," instead of, "What happened?" Affirming is more efficient in dialogue but can also be implemented, with patience, in other modes of interaction, such as email or live chats.

Next, we can move to challenging the student, but gently, using questions. The goal here is to get a better picture of the situation and to aid the student's self-discovery of possibly inaccurate self-perceptions about their level of understanding and learning processes. This spans assessing a student's readiness and exploring a student's ambivalence to making changes to their learning behaviors. In this case, we could ask our struggling student, "How do you know you understand the material?" It is challenging their claim of knowing, but gently and without assuming. It asks for the evidence they are using to support the claim, which they may have but did not articulate previously or may be lacking. It opens the door to help a student become aware of their need to make adjustments to their approaches to learning if they lack that awareness. In electronic communications, we recommend limiting to one or two questions at a time, giving space for answers, and empathetic listening to guide further interactions. This avoids overwhelming the student and unwittingly making assumptions.

At this point, the "evidence" may be vague and based on faulty perceptions. Students commonly respond with things like "I reviewed my notes" or "I looked over my homework" or yet again, "I worked several practice exams." We need to continue to gently press for more specific and concrete evidence. For example, "What does it mean to 'review' your notes?" In following up, there is an opportunity to help the student see that while they understood their notes when they "reviewed" them, it may not translate into them being able to solve new problems on their own. Svinicki (2004) calls this the "Illusion of Comprehension." Once recognized, it sets up an opportunity for asking for and sharing better alternatives.

Finally, we want to be encouraging to our students, that is, to share our sincere belief in their ability to make changes and to become more skillful learners - with persistent effort over time, of course. While motivational interviewing aims to elicit intrinsic motivation within an individual, this is additional external support for developing student self-efficacy. It can help build trust with the student that we seek to support in progressing toward their goals. We can reinforce options they have come up with or, with

their permission, also offer a few specific suggestions for what they can do. For example, in a problem-solving course, the educator can reinforce the student's idea to create extensions or adaptations to example problems or they can suggest that students make up their own problems – both are elaborative strategies known to deepen learning by promoting connections with existing knowledge. Elaborative strategies help students integrate their knowledge, which makes it more useful to them. When the educator gives options, they must be careful not to overwhelm. One to three options are enough, and let students choose. It is preferable to reinforce or expand good options they offered from the educators Challenge questions, as described above.

Using A²CE to provide feedback

An example will help illustrate how to generate A²CE feedback for a student. The setting is a student response to a question about their learning habits. In training faculty on the A²CE and its use, we draw from actual data to provide an example for the educator participants at our workshops. The context for the student response was the following prompt provided after they had completed one of our modules on metacognition (Table 1):

“Name one new thing you have been doing since completing the module on Knowing About Thinking. How is it helping you be a more skilled and efficient learner?”

During the faculty workshops, we provide an example of a common response that we received from students:

“I get together and talk through homework problems with my friends now. This is helpful because by teaching it to someone else, it gives me a stronger understanding of the material.”

Note that the prompt asked for a strategy (the new practice or action that the student is doing) and evidence that it is working (evidence). For this response, the two elements are identified in Table 2. Because the question asks for two elements, it is important to give feedback on both.

Employing the A²CE framework, we first adjust our mindset, *acknowledging* that we gave limited space and time for the student to respond, and there is likely more to their claim than what is written. A potential *affirmation* could be, “Good! Explaining your understanding can help you build connections and test your level of understanding.” It affirms the value

Table 2. Strategy and evidence components in a student's response to a question about their learning processes. These classifications are made prior to judging the quality of the strategy or evidence.

Strategy	I get together and talk through homework problems with my friends now
Evidence	This is helpful because by teaching it to someone else, it gives me a stronger understanding of the material.

of explaining to learn, a good elaborative strategy. However, the evidence cited is weak, if it is evidence at all.

An opening *challenge* question might be, “What evidence helps you know you have a stronger understanding?” This question does not assume that the evidence does not exist. It may, and just not have been included in the response. Nor does it assume it does exist. This question is an effective exploratory question and embodies a respectful challenge. It is important to note that how the educator proceeds from here will depend on their mode of communication. If the educator is meeting face-to-face with the student, they may be able to follow-up with additional questions pressing for more detail and inspiring the student to deeper reflection. We recommend limiting challenge questions to one or two when interacting virtually and asynchronously. Limiting challenge questions helps avoid overwhelming the student and helps the educator avoid making assumptions about the student. In such electronic communication, the educator may also want to invite further dialogue, giving the student an opportunity for follow-up.

To leave the student with *encouragement*, you could say, “Keep on explaining to learn! You could use self-testing, recall-and-review (a.k.a, retrieval practice), or timing your solutions to accurately self-assess your understanding.” It encourages their initial attempts with a beneficial learning strategy and offers suggestions for ways to gather better evidence for their understanding. Of course, the options and encouragement the educator offers will depend on a student's answers to the challenge questions. (See additional examples of A²CE feedback available on <https://skillful-learning.org/resources/>)

Evaluation of the A²CE framework

To understand the functionality of the A²CE framework, we gathered data from educators via practice-informed research as defined by Jamieson and Lohmann (2009). Specifically, the A²CE framework was presented at several workshops where we trained educators in creating learning activities to help engineering students learn metacognition and

specifically how to use this framework to provide feedback to students on such learning. We collected data from educator participants at one such workshop in an effort to evaluate the functionality of the A²CE framework. Approximately 30 educators interested in implementing techniques in their classes to build metacognitive skills attended the workshop. The research was conducted in accordance with approved human subjects research protocols, covered by the Virginia Tech Institutional Review Board, protocol #19-625.

Within the workshop, the A²CE framework was presented within a practical context of working with actual student responses to questions regarding what new learning strategies they had been using and how they knew they were working. Participants had interacted with these statements earlier in the workshop, where they identified stated strategies and evidence students cited to support strategy effectiveness. Before participants used the A²CE framework, the A²CE framework was defined, and an example of possible feedback was given, demonstrating each element, such as presented in the previous section. The participants worked with one or two neighbors to draft feedback for at least two of five student responses. The workshop culminated in participants sharing examples of feedback they generated and discussion of alternatives and different assumptions behind the drafts. The workshop's goal was to have participants not just hear about the A²CE framework but to engage in a significant experience practicing its application and refining their understanding through discussion.

Method for collecting educator feedback

Of the workshop participants, 23 participants consented for their evaluations to be used for research purposes. No demographic or identifying information was requested on the evaluation forms. Our evaluation included open-ended reflection questions prior to the start of the workshop and different open-ended questions at the end of the workshop. The questions before the workshop asked how participants currently provided feedback to their students regarding the students' process of learning and what challenges participants associated with providing feedback on students' learning processes. The questions asked after the workshop focused on the use of the A²CE framework and included participants' thoughts on using the A²CE framework as a feedback mechanism on students' process of learning, plans (affirmative or negative) on using A²CE and why, what could improve the usefulness of A²CE, and in what context

might the A²CE framework be useful in their work with students. Note that before and after workshop questions are not intended for direct comparison as they differ in content but are intended to establish if the A²CE framework is capable of filling existing gaps in understanding useful practices for offering feedback.

To analyze our data, authors Ellestad and Carrico conducted open coding of the responses, followed by grouping and categorizing (Miles & Huberman, 1994). Consistent with open coding, Ellestad and Carrico read the entire transcripts and then coded (labeled) excerpts to describe the meaning within each transcript related to "student feedback." Further, labels were used to describe items such as the participants' need(s) for providing feedback to students, issues with giving feedback, strategies used, and value provided relative to the phenomenon. Ellestad and Carrico independently created labels and then compared and refined their labels and definitions, resulting in relationships among some of the labels (axial coding). Ellestad and Carrico then developed themes from the relationships and patterns considered between the pre and post reflection questions. The entire author team (including Cunningham and Matusovich) reviewed and discussed the analysis for agreement on the interpretation of the results.

Results of the educator evaluation

The pre-workshop questions focused on the kinds and format of the feedback given and educators' need for support to provide student feedback on the process of learning. Our analysis revealed three key findings related to feedback: content, direction, and challenges. Table 3 provides examples of comments for each result.

From these results we summarized that feedback is typically unidirectional feedback from instructor to student and strategies reported do not engage students in a conversation about their learning, but instead only provide suggestions on how to improve. Participants also described a tendency to focus on providing more feedback on technical competency and less on learning development. This lack of feedback on learning development could be due in part to low self-efficacy and perceived lack of competence in providing this type of feedback. This is consistent with prior interviews with faculty citing a lack of confidence in talking about metacognition (Williams et al., 2016), which led to the development of the A²CE framework.

Recall that the post-workshop questions are not a direct repeat of the pre-workshop questions and

Table 3. Pre-workshop educator reflections provided a view of their perceptions and practices with giving students feedback before encountering the A²CE framework.

Initial Feedback Themes	Examples
<i>Feedback Content:</i> Technical content focus vs. learning process focus	<ul style="list-style-type: none"> • Often written comments on these assignments or verbal feedback during office hours. • Primarily passive feedback. • "I give them a grade. When I have project courses, I also give them comments about what they did, and about what I was expecting them to do. Or I give them ideas about what they could do to improve what they are doing." • "[I use] Checkmarks and Xs on submitted assignments with some brief commentary on where the student made a mistake. I've often written, 'come see me in the office hours' on assignments when problems aren't attempted or the student writes they don't know how to solve the problem." • "Very little feedback is given on their actual learning process."
<i>Feedback Direction:</i> unidirectional; Educator to student	<ul style="list-style-type: none"> • Methods of feedback included rubrics, written comments, and verbal. • Missing from the data were comments on discussions during feedback or soliciting what students' thoughts on why they did what they did. • "In-class board work (student groups). I circulate the room and provide feedback based on what I see students writing (solving problems) on their group's board."
<i>Challenges:</i> Student-focused (Notably, the question asked about participants' challenges giving feedback but responses were predominantly student-focused.)	<ul style="list-style-type: none"> • Barrier of students being focused on grades or tasks versus learning. • Barrier of student resistance to new learning techniques. i.e., not being open to educators' suggestions as being helpful. • "students are reluctant to try something I suggest that they didn't think of on their own or that their friends aren't doing"
<i>Challenges:</i> Teacher focused	<ul style="list-style-type: none"> • Few responses related to participants' barriers. • Barriers tended to be outside of participants, control, e.g., time and uncertainty of value to the student. • Barrier within the participants' control was lack of confidence to provide learning process feedback.

Table 4. Post-workshop educator feedback on A²CE framework provided insights into how they value and their potential use of the A²CE framework.

Feedback Themes	Examples
<i>Student-centered:</i> Areas of benefit/improvement for student learning	<ul style="list-style-type: none"> • <i>Benefit:</i> Good way to show caring toward students • <i>Benefit:</i> Improve relationships with students while providing challenging feedback <ul style="list-style-type: none"> • "I am often "preachy" so this is a way to be more student-focused and help students come up with strategies on their own instead of me telling them." • <i>Benefit:</i> Opportunity to build better relationships with students • <i>Benefit:</i> Improve communication between faculty and students on learning processes • <i>Benefit:</i> Provides method for gentler conversations on how to improve learning • <i>Benefit:</i> Meaningful and respectful way to provide student support
<i>Teacher-centered:</i> Areas of benefit/improvement for educator implementation	<ul style="list-style-type: none"> • <i>Benefit:</i> Realization that they were providing some learning feedback • <i>Benefit:</i> Easy and fast to use • <i>Needs Improvement:</i> Lack qualifications to use the A²CE framework <ul style="list-style-type: none"> • Requested to learn more from module videos • <i>Needs Improvement:</i> Comprehensive list of learning strategies to use during Challenge phase could support use • <i>Needs Improvement:</i> Need more examples of applying the A²CE with real student comments for training • <i>Needs Improvement:</i> Concerned about time to implement in classes
<i>Framework-centered:</i> Areas of benefit/improvement on the framework	<ul style="list-style-type: none"> • <i>Benefit:</i> Importance of the affirming and encouraging portion; participants tend to only focus on challenging <ul style="list-style-type: none"> • "the A&E are just as important as C" • "we tend to only focus on the challenging portion when talking with students" • "the believing [acknowledging] portion is most important - we need to not make assumptions and listen to students"

instead focused on the perceived utility of the framework as a means to provide feedback. When asked in the post-workshop survey if participants would use the A²CE framework, the overwhelming majority indicated "yes," though a few indicated that they would not. The post-workshop results regarding initial thoughts of using A²CE as a framework to provide feedback on students' process of learning were more student-centered than the pre-workshop responses.

Therefore, the post-workshop responses were categorized into student-centered, teacher-centered, and framework-centered and are summarized in Table 4. Responses focused on perceived benefits (labeled *Benefit*) as well as areas for improvement (labeled *Needs Improvement*).

Participants' post-workshop feedback communicates the benefits of the A²CE to both students and instructors. Some participants focused on the

benefits of the conversation that can take place when using the A²CE, thus minimizing the potential of unidirectional feedback. After engaging in the workshop, several participants realized that they had indeed been providing learning feedback in the past, and this method provided more structure for doing so. While many benefits were identified in post-workshop feedback, several participants identified areas for improvement, specifically in the development of a comprehensive list of learning strategies and more examples of the A²CE applied to student comments for further training. These suggestions for improvement are ways to increase the competence and confidence of instructors as they seek to use the A²CE.

Limitations

All of the educators surveyed about the use of the A²CE framework were in attendance at a workshop focused on learning how to help students develop metacognitive skills. By only asking educators who elected to attend this metacognition workshop, we realize that there is a self-selection bias in the survey results. We do believe that this self-selection bias is somewhat mitigated by the fact that the purpose of collecting feedback on the A²CE framework is to understand, from educators who were likely to use the framework, how efficacious it would be in supporting them and ways in which we might improve the tool.

Conclusions

To develop self-regulated learners, we need to be able to provide feedback on students' learning processes, and this can be challenging for educators. The A²CE feedback framework provides a practical and scalable way to do this as formative feedback for students. This is of particular importance in engineering, where classes are often large, and educators are loath to talk about learning rather than content. Our work recognizes and values the premise that metacognition develops over time, and supporting this development in students requires multiple cycles of instruction, intentional practice, and constructive feedback. Our A²CE feedback framework is an integral part of this cycle as it aids educators in providing constructive feedback that is formative, actionable, and designed to help students make more accurate self-assessments while they build their metacognitive knowledge and

skills. We believe that the A²CE framework fills a gap because educators indicated a need for more support in having meaningful conversations with their students about learning processes. They also indicated that the A²CE framework provides a method for having caring conversations about students' pursuits in learning while giving constructive feedback that students can use to improve their learning skills both in and out of the classroom. We believe the A²CE provides a starting point for future training on the types of learning strategies educators can suggest to individual students who are in different learning situations as they move through engineering curricula.

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