



Integrating Reflection into Engineering Education

Dr. Jennifer A Turns, University of Washington

Dr. Brook Sattler, University of Washington

Dr. Ken Yasuhara, Center for Engineering Learning & Teaching (CELT)

Dr. Jim L Borgford-Parnell, University of Washington

Dr. Jim Borgford-Parnell is Associate Director and Instructional Consultant at the Center for Engineering Learning & Teaching at the University of Washington. He taught design, education-research methods, and adult and higher education theory and pedagogy courses for over 30 years. He has been involved in instructional development for 18 years, and currently does both research and instructional development in engineering education. Jim has taught courses on the development of reflective teaching practices, and has presented workshops on learning how to learn and developing metacognitive awareness.

Dr. Cynthia J. Atman, University of Washington

Cynthia J. Atman is the founding director of the Center for Engineering Learning & Teaching (CELT), a professor in Human Centered Design & Engineering, and the inaugural holder of the Mitchell T. & Lella Blanche Bowie Endowed Chair at the University of Washington. She also directed the national NSF-funded Center for the Advancement of Engineering Education (CAEE). Her research centers on engineering design learning with a focus on issues of context in design.

Integrating Reflection on Experience into Engineering Education

Jennifer Turns, Brook Sattler, Ken Yasuhara, Jim Borgford-Parnell and Cynthia J. Atman

Introduction

Assigning meaning to experiences is something we do all the time. Words are interpreted as friendly or rude, job performances as successful or unsuccessful, reactions of interest or boredom as evidence of whether we are well suited for our current jobs or careers. Moreover, these meanings have consequences—we take action based on how we interpret or make meaning of experiences. We may respond differently to a question based on whether we interpret it as rude or not, and we may approach our next job based on our interpretation of the success of a current activity. *Meanings matter.*

Often, the assignment of meaning is tacit. In fact, people spend a great deal of time learning to associate certain experiences with certain meanings (i.e., to make meaning of experiences as others do). At the same time, there are usually multiple ways to interpret or make meaning of experiences, and how we make meaning has consequences. Moreover, our lenses for making meaning are themselves often subject to change.

In this paper, we focus on reflection on experience as an intentional form of thinking where a person revisits an experience with a specific meaning making lens. While reflection has not historically received a great deal of attention in engineering education scholarship, we are motivated by calls for greater consideration of reflection. For example, in her National Academies piece calling for curricular change in undergraduate engineering, Ambrose notes that “...students learn by doing, but only when they have time to reflect—the two go hand in hand. Why, then, don’t engineering curricula provide constant structured opportunities and time to ensure that continual reflection takes place?” (p.1).³⁰ There is opportunity for more research on and efforts to support reflection in engineering education. Our goal is to provide resources for such activities.

As a scholarly effort, this paper represents a scholarship of integration—we aim to help other scholars by drawing together various strands of work related to reflection. To this end, we start by introducing a framework for thinking about reflection and discussing example instantiations of the framework. In subsequent sections, we identify theoretical work that motivated our framework and is likely to be of interest to anyone interested in reflection. We then discuss efforts to support reflection in the contexts of professional education, life and engineering education. We close by discussing how the ideas we have presented can be used to support efforts to research or support reflection in engineering education.

A framework for thinking about elements of reflection

Reflection on experience can be framed as an *intentional* and *dialectical* thinking process where an individual revisits *features* of an *experience* with which he/she is aware and uses one or more *lenses* in order to assign *meaning(s)* to the experience that can guide future *action* (and thus future experience). We can use *pathways of reflection* to delineate combinations of these elements. In this section, we unpack the elements of this framing (i.e., experience, lens, meaning,

action, intentional, and dialectical) of reflection and then illustrate the ideas through a single extended example and a discussion of other possible examples.

Elements of reflection

- Experience: An experience can be understood as engagement with the world, roughly circumscribed by time. For example, we can think about the experience of getting good news, the experience of doing homework, the experience of traveling abroad, and the experience of being a teenager.
- Features: Features of an experience are those aspects of an experience with which an individual is aware. Put another way, the features of the experience are those that can be described by an individual. For a given experience, for example, we might be aware of the time involved, what surprises us, our physiological response, etc.
- Lens: We use lens to refer to the knowledge that is being used to interpret or make meaning of specific features of an experience. For example, we can interpret features an experience using understanding of a particular subject matter (e.g., engineering), understanding of self (i.e., an identity lens), or understanding of social justice.
- Meaning: Meaning refers to the specific understanding of the experience that results from using the lens to interpret the features. For example, a student, reflecting on an activity's difficulty (i.e., the feature) using some type of productivity lens, might come to an understanding of ways in which the activity could be done more effectively.
- Action: Action refers to steps taken as a result of the meaning that has been ascribed to the experience. In educational contexts, actions might include studying in a different way, seeking out a professor in office hours, and choosing specific classes to take.
- Intentional: We refer to reflection on experience as an intentional process in order to signify that reflection on experience involves a person actively and knowingly engaging in the meaning making process. This element of reflection is important to note because much meaning making occurs implicitly (such as the example given in the introduction of interpreting a behavior as rude or not rude).
- Dialectical: Dialectical is used to describe phenomena that are concerned with or act through opposing forces. In the context of reflection on experience, dialectical refers to the tensions between using an existing lens *as is* in order to make meaning of an experience and revising the lens to account for features of the experience (such as reframing one's sense of identity given an experience of enjoying a particular activity).

To illustrate how these elements might play out engineering education, the following section provides an example related to an experience common in engineering student life—doing homework. In the subsequent section, we broaden the discussion of possible examples.

Reflecting on a homework session

Consider the following scenario. Students in a thermodynamics class are asked to work on a homework in which thermodynamics content is situated in a third world scenario. Upon completion of the problem, one student, frustrated by how long the homework session took, starts thinking about how to solve the homework problems more effectively. A second student,

also troubled by how long the homework took and how hard it seems, spends some time thinking about whether engineering is the best major for her. A third student, intrigued by the application of the class content to third world challenges, starts to think about how engineering really can be useful in such a situation.

This specific example is intended to illustrate possible reflection pathways associated with homework. Following any given homework experience, a student may be aware of features of that experience such as how long it took, their level of engagement, and perhaps their success in solving the assignment problems. The student who is engaged in intentional meaning making can interpret these features through different lenses, such as the ones described above. The example is intended to illustrate possible combinations.

Consider the first student who “starts thinking about how to solve the problem more effectively.” This student’s reflective challenge is to determine how to interpret features such as the length of time required to do the problem and his/her frustration with the length of time spent. In addition, the student may be aware of other features of the experience such as where specifically the time was spent, the types of representations used in solving the problems, and the types of resources used in solving the problem.

A student reflecting in this situation might use existing ideas about effectiveness to come to the meaning that representations suggested by the teacher really are helpful (or alternately are not actually helpful.) Or, perhaps the student thinks, “since I studied a long time and still did poorly on the homework, I think my approaches to learning the material are faulty and I need to revisit my ideas about learning.” It is also possible that the meaning making might take the following form, “because the question I got wrong was one that I really thought was correct, I need to go back and re-evaluate my level of understanding of the material.” Given the meanings that are ultimately assigned to features of the problem solving experience, what actions could follow? In this case, different meanings could lead to different strategies used in subsequent problem solving efforts.

Consider the student who “starts thinking about whether engineering is the best major for her.” This student’s reflective challenge is to determine how to interpret features of her experience in terms of their meaning using an identity lens. For example, should her concerns about the difficulty of the subject matter be interpreted as meaning that she does not belong, or does she determine that her difficulty is evidence that she is just like everyone else? Then, given the meaning that is ultimately assigned, what actions could follow in this case?

Finally, consider the student who “starts to think about how engineering really can be useful in such a situation.” This student’s reflective challenge is to determine how to interpret her surprise at the instructor’s ability to connect the material to societal issues. Should her surprise be interpreted as an isolated rare instance or a cue that she should re-evaluate her beliefs (i.e., her lens) about the subject matter as societally useful? And, given the meaning that is ultimately assigned, what actions could follow? For example, if the student determines that the surprise means that she thought the class was irrelevant but now understands that the class is relevant, this could affect actions related to doing future homework, asking questions, etc. But, what if the student determines, more fundamentally, that her “lens” concerning how engineering in general

can help solve problems? Such a refined lens could lead to quite different actions.

Other reflection examples

The above example is intended to illustrate the framework that we have offered for thinking about reflection on experience. Clearly, we could have written many other example scenarios. For example, we could have described reflection pathways associated with experiences in team meetings, dealing with open-ended design problems, studying abroad, etc. Further, in such examples, we could have illustrated how lenses such as learning, preparedness, and professional identity would have been used. Such enumeration of example scenarios is, in fact, something that could be valuable for the engineering education community and is thus one area of additional research.

Reflection situated in theory

Reflection has been the subject of significant scholarly work. We begin with perspectives that explicitly use the term reflection. We then turn to perspectives that use different terms and have different foci, but also have significant overlap with reflection. In concluding this section, we touch on the relationship between reflection and metacognition.

Reflection theorized

Much of the work on reflection builds on the work of four theorists: Dewey,¹⁻² Kolb,³ Schon,⁴ and Mezirow.⁵ While each theorist approaches the topic differently, the ideas presented by the theorists align around a sense of reflection as intentionally making meaning of experiences in service of future action.

- Dewey: Dewey¹⁻² is widely recognized for his work related to education generally. In much of his work he focuses on the importance of experience and what makes an experience meaningful, which for him means that the experience has the potential to lead to learning. In thinking about helping move experiences to meaningful experiences, Dewey emphasizes the importance of connecting experiences through “a backward and forward connection” (p. 77).²
- Kolb: Kolb³ contributes to our understanding of reflection through his well-known Experiential Learning Model (ELM). In this model, he emphasizes the importance of four cyclic elements of concrete experience, observation of and reflection of that experience, formation of abstract concepts based upon the reflection, and testing new concepts.
- Schon: Building on the work of Dewey¹⁻², Schon⁴ was a strong proponent of reflection as a key to professional activity. In his work, he theorized “reflective practice,” “reflection on action,” and specifically “reflection in action.” Moreover, Schon is widely recognized as calling attention to reflection-in-action as a key practice that professionals use in order to handle the complex problems of professional practice.
- Mezirow: In his work on transformative learning, Mezirow⁵ draws attention to *critical* reflection, a process of questioning assumptions (or questioning “lenses” in our framework). “Critical reflection enables individuals to review what they know from their

experiences in the light of current circumstances, transforming their perspectives in the light of their developing identity, current decisions and actions, and future goals.”⁸ This is a type of learning that is embedded in lifelong learning. Merirow’s emphasis on critical reflection links to others with similar emphases.⁶⁻⁷

Related perspectives

In this section, we characterize perspectives that are related to reflection. These perspectives come from scholarship conducted with varied intentions (e.g. to create healthier organizations with less attrition, to explain child development, and to explain how professionals function) and across varied contexts (e.g., K-12 and workplace). The perspectives presented below have a strong focus on intentionality.

- Sense making: Scholars in the disciplines of information systems⁹⁻¹² and organization studies¹² draw on the notion of sense making in their work. Sense making represents an exploration of workers’ “cognitive gaps” as they try to make sense of data. These two disciplines recognize sense making as a fundamental workplace activity, helping workers conduct their jobs better. The ideas of sense making and meaning making are quite resonant.
- Single-loop and double-loop learning: Researchers in management draw on the ideas of single-loop and double-loop learning to understand activity and learning within organizations.¹³ Single-loop learning involves improvement narrowly—learning that permits achieving the same goal better but does not involve questioning or modifying the goal. Double-loop learning involves learning to question or modify the goal. This distinction bears similarity to the distinction between reflection as discussed by Dewey, Kolb, and Schon and critical reflection as discussed by Mezirow.
- Assimilation and accommodation: In his work on cognitive development, Piaget described how children engage in the processes of assimilation and accommodation.¹⁴ Piaget described these as taking in new information by fitting the information into current ways of knowing (assimilation) or using new information as a trigger to adjust current ways of knowing (accommodation). As with the single-loop/double-loop learning distinction, the distinction between assimilation and accommodation bears similarity to the distinction between reflection and critical reflection.

Sense making, single-loop and double-loop learning, and accommodation and assimilation represent theoretical perspectives that bear similarity with features of reflection as we have characterized it. A more extended list might include the concepts of disjuncture (from adult learning) and the concept of self-authorship (from the developmental literature).

Reflection and Metacognition

In educational contexts, reflection is frequently discussed alongside the concept of metacognition (consider, for example, the book titled *Using reflection and metacognition to improve student learning: Across the disciplines, across the academy*¹⁶). Such a co-occurrence of the concepts makes sense given a general sense of metacognition as knowing about knowing¹⁵, and our framing of reflection as intentional meaning making. While the co-occurrence makes sense, the

specific relationship between reflection and meta-cognition is more challenging to sort out.

It is possible that efforts to bring the two concepts together really have one of the concepts as the central emphasis. For example, in the book mentioned above, while the title incorporates both concepts, the content of the book focuses more on metacognition than reflection.¹⁶ This could further be related to the observation that metacognition and reflection stem from relatively different scholarly communities.

In general, metacognition and reflection (per our definition) seem quite related when the metacognitive concepts of self-awareness and self-assessment are the metacognitive issues being foregrounded. The relationship between reflection and metacognition seems less clear when the metacognitive concepts of tip-of-the-tongue and meta-emotion are the emphasis. This lack of clarity suggests that clarifying the relationship between the two concepts is a useful area of investigation.

Reflection in different contexts

As we mentioned in the introduction, our goal is to provide resources for research on, and efforts to support, reflection in engineering education. Because work on reflection in engineering education and beyond represents such resources, we turn to such work in this section. We start by providing a sample of the work in professional education contexts and also work related to general life activity. We then turn to work in engineering education.

Reflection and Professional Education

Reflection is a relatively prominent topic in professional education. For example, in her work—“Handbook of Reflection and Reflective Inquiry: Mapping a way of knowing for professional reflective inquiry”—Lyons emphasizes the important role of reflection in professional education.¹⁷ The domains discussed in this handbook represent a wide range of professional disciplines from medicine, in which reflection may be critical to life or death, to management, in which reflection may be influential to a company’s bottom line.

In medical education, reflection is a prominent topic because “reflective capacity is regarded by many as an essential characteristic for professional competence” (p. 595).¹⁸ Mann, Gordon, and MacLeod offer a systematic literature review focused on reflection and reflective practice in health professions education.¹⁸ In this work, they address the following six questions: (1) Do practicing health professionals engage in reflective practice? (2) What is the nature of students’ reflective thinking? (3) Can reflective thinking be assessed? (4) Can reflective thinking be developed? (5) What contextual influences hinder or enable the development of reflection and reflective capability? and (6) What are the potential positive and negative effects of promoting reflection? They report finding that reflection is a prominent topic in medical education and “is demonstrated among practicing professionals” (p. 610).¹⁸ However, in pointing out that research focusing on strategies for fostering reflection is still limited, they note: “We identified only 29 studies, the majority of which were observational in nature” (p. 609).¹⁸

In a more specific medical education discipline, Bennett-Levy and Padesky explored the role of

reflection in the professional development of therapists.¹⁹ In their work, they note that therapists attend professional development workshops, but often the workshops are ineffective for learning and utilization of skills without follow-up. In the study that they report, they “tested the hypothesis that creating opportunities to reflect in the weeks following a workshop would enhance learning and utilization of skills” (p.1).¹⁹ They found that therapists who engaged in workshop supported reflection activities “reported enhanced use of new skills with clients and a trend towards increased awareness of workshop learning. Further analysis revealed that group differences were almost entirely linked to use of follow-up reflection worksheets” (p. 1).¹⁹ Their work demonstrates that reflection activities can lead to learning gains.

In the literature on teaching and teacher education, reflection is a discernible theme. In fact, those who educate future teachers often are required, by professional standards, to prepare future teachers to be able to reflect. In other words, the ability to reflect on experience is a competence included in some of the professional standards related to teaching. A prominent area of research on reflection in teaching and teacher education is critical reflection.⁶ In critical reflection, educators identify, assess, and transform assumptions (or lenses in our framework).

In nursing, researchers have explored the role of reflection in nursing activities, such as education, professional development, and decision-making. In one recent study, researchers focused on the importance of engaging in reflection in nursing practice and educating nurses to be reflective practitioners.²⁰ Specifically, the researchers offer a practical template for teaching reflective thinking. The template—SAFETY—guides students through areas for reflection that are critical areas of nursing. The scaffolding of reflection through the SAFETY template provides nursing students with opportunities to engage in the clinical reasoning process.

Reflection and Life

Moving beyond professional education, this section highlights work related to reflection in areas such as search behavior and health and wellness, and done by scholars from different communities.

Researchers in human-computer interactions (HCI) participated in a workshop dedicated to the theme: “Designing for Reflection on Experience.” It is notable that an entire workshop from this community was dedicated to the topic of reflection. The topics of discussion ranged from the importance of reflection in the control room²¹ to specific technologies that support reflection²²⁻²⁵ to games that foster reflection²⁶. In one article of particular interest, the author explored the role of reflection in helping people imagine potential technologies.²⁷ The findings of this study demonstrate that “purposeful engagement of technology [can be used to] envision and manage the fulfillment of the Ideal Self” (p.1).²⁷

In research on search behavior, Bateman, Teevan, and White explored how integrated reflection could help people become more experts at online search.²⁸ They developed a tool (i.e., the Search Dashboard) that supported people in reflecting on their own search behavior. The results of this study suggest that when people reflect on their search behavior they become better searchers.

In other areas of life, such as health and wellness, we can see the role reflection is playing to help people better manage their overall well-being. For example, Grimes, Tan, and Morris explored “the implications of collecting, sharing, and reflecting upon health information within families” (p. 311).²⁹ The authors suggest that as researchers and scholars design technology for health and wellness, consideration should be given to the importance of reflection.

While it is not clear how large the body of research on research and life actually is, it is clear that interesting work is being done. These brief snapshots suggest opportunities to further explore these areas for lessons related to understanding and supporting. In the next section, we specifically explore what is currently going on in engineering education.

Reflection and engineering education

Reflection has not been a prominent scholarly area of research in engineering education. In her National Academies piece calling for curricular change in undergraduate engineering, Ambrose notes: “So, yes, students learn by doing, but only when they have time to reflect—the two go hand in hand. Why, then, don’t engineering curricula provide constant structured opportunities and time to ensure that continual reflection takes place?” (p.1).³⁰ While such constant opportunities may not be the norm, there is work to build on. Scholars have offered frameworks to support student reflection³¹ and used reflective practices as a means to understand engineering student teamwork³².

Walther, Sochacka, and Kellam explore emotional indicators as a way to initiate student reflection in engineering programs.³¹ In this work, they acknowledge a need to “stimulate purposeful student reflection” (p.1),³¹ but also note that the community has few strategies to address such a need. Building on data from student focus groups that were reflective in nature, the researchers offer a framework that can help other educators stimulate reflection.

In their work on design in engineering education, Hirsch and McKenna explore using reflection to promote the community’s understand of teamwork and how to support students in teamwork.³² First, they draw attention to the importance of teamwork and characterize how little is known about providing instruction to teams. To better support students in teams, they focus on pedagogical approaches that feature reflective activities as an opportunity to support engineering students in teamwork.

In an effort to support educators, McKenna, Yalvac, and Light explored “the role of collaborative reflection in shaping engineering faculty teaching approaches” (p. 1).³³ Their findings suggest “faculty with extensive engagement in reflective education activities showed more favorable approaches toward learner-centered, student-focused teaching and faculty with minimal engagement [leaned] toward a more knowledge transmission, teacher focused approach” (p. 23).³³ The contribution of their work includes guidance in using collaborative reflection in faculty development programs.

Kavanagh and O’Moore reflect on how the University of Queensland (UQ) has integrated reflection into undergraduate engineering education over the last ten years.⁴³ The institutional change at UQ was driven by the emphasis on “*equipping graduates with not only technical, but*

also communicative and social competencies (Mitchell et al 1998)” (p. 1).³⁴ The authors report that reflection was being integrated in various ways: reflection journals, portfolio reflection, end of course meta-learning, peer assisted learning session, online reflections, and team reflections. While the authors note the dedication to reflective activities, they also note opportunities to more systematically incorporate reflection into undergraduate engineering education.

In earlier work on reflection in engineering, Turns, Newstetter, Allen, and Mistree report on the design of the “Reflective Learner”: an electronic system to support students in the writing of learning essays.³⁵ They argued that “learning essays can help students expand and enhance lessons that they are learning from design experiences” (p. 1).³⁵ The learning essays are described as short and structured with the goal of helping students learn from their experiences. The system is described as using two types of scaffolding: content and structure. Through content scaffolding, the system offered students suggestions concerning potential essay topics (i.e., suggestions of topics upon which the students could reflect). Through structure scaffolding, the system prompted students to engage in different elements of reflection. The findings of their research show that most students voluntarily used the “Reflective Learner” electronic system to reflect. They also found that there was evidence that quality of students’ essays improved through the use of the tool.

What is striking about the body of research on reflection in engineering education is the limited number of publications. While care must be taken in drawing inferences about the role of reflection in engineering education based on the number of research publications, the limited number does suggest opportunities for more investigation of the issue. In the next section, we discuss how the framework presented earlier can be useful in thinking about such investigation.

Researching and supporting reflection

In engineering education, there is opportunity to explore questions such as (a) what opportunities for reflection might students already have, (b) what could be done to help students have more opportunities for reflection, and (c) what could be done to support students in engaging in reflection? In this section, we address such questions via a systematic analysis that leverages the reflection framework introduced earlier. Specifically, we noted that reflection on experience can be framed as an *intentional* and *dialectical* thinking process where an individual revisits *features* of an *experience* with which he/she is aware and uses one or more *lenses* in order to assign *meaning(s)* to the experience that can guide future *action* (and thus future experience).

Experiences: Since reflection on experience clearly involves experience, a useful area of investigation is to consider the range of experiences that students currently have. It is natural to be drawn to thinking about student *experiences* such as large-scale projects, co-op opportunities, and internship opportunities. What is possible to overlook is the range of other experiences that students are having. Such experiences include everyday schooling experiences related to learning, engaging with others, communicating, etc. The range of other experiences also includes co-curricular activities, extra-curricular activities, and even larger life experiences that may have relevance for engineering education. In terms of supporting reflection, one point would be to think about whether students are getting a broad array of experiences, and how to craft student experiences so that they will provide students with opportunities to reflect on

particular issues of interest (e.g., professional identity, collaboration, and social justice).

Features of experience: Reflecting on an experience is more precisely reflecting on the features of the experience with which one is aware. Thus, an important area of investigation involves better understanding of the features of experiences with which students are typically aware and how to support greater awareness. Ways to support greater awareness might include prompting students to record reactions to an experience (e.g., what surprised them, frustrated they, pleased them), asking students to collect and share artifacts and then leveraging the artifact to stimulate recall, and finding ways to help students monitor features such as time on task and their engagement. Psychological research methodologies such as experience sampling and technologies that can provide traces of experience (e.g., videos, coded behavior, transcriptions) can be helpful.

Lens for meaning making: Reflecting on an experience involves using a specific lens in order to make meaning of the experience. For example, one can reflect on an experience in terms of effectiveness (i.e., did it go well), learning (i.e., what did I learn), preparedness (i.e., how did my recent experience prepare me for x), identity (i.e., what does this say about who I am), and social justice (i.e., how can I use my recent experience to think more critically about social justice). Thinking about the issue of lenses raises a number of interesting questions related to investigating and/or supporting reflection. For example, how sophisticated are student's lenses, how do students choose what lens to apply when engaging in reflection, how aware are students of the lenses that they bring, what are the different levels of difficulty associated with applying a particular lens, what difficulties arise when choosing a lens, and are there fundamental human abilities that make it easier to choose lenses and see events from multiple perspectives? Opportunities to support reflection can follow from answers to such questions.

Meanings. Core to reflection is the assignment of a meaning to an experience. For example, it is through reflection that we address such issues as whether a recent meeting was a "good or bad" meeting and what our recent performance in a given context suggests about "whether we fit." In terms of investigating reflection, it would be interesting to know more about the meanings that result from intentional reflection alongside the meanings that students arrive without such intentional reflection, as well as the consequence of different meanings. Such an analysis would make it possible to address the question, what might the cost of not taking the time to reflect? In terms of supporting reflection, it is interesting to note that the assignment of meaning is where reflection can become challenging, controversial, or otherwise problematic. Thus, supporting reflection might entail helping create a safe environment for reflection and supporting students even as they work through unpopular meanings for their experiences. Reflection has been described as subversive and political, and such descriptors are particularly salient at the meaning making moment where students may start to grapple with how they have *been* socialized to understand an experience and how their *current* reflective processes lead them to understand the experience. Supporting students in reflecting may involve recognizing and calling out these types of challenges to students.

Actions. Ideally, reflection efforts result in some action. In the context of engineering education, actions could include pursuing new studying strategies, seeking out help, seeking out future experiences with specific properties, and/or making choices about one's education. Efforts to

investigate reflection could explore action-related questions such whether engineering students typically bring action into their reflection efforts, what types of actions result from reflection activities, and whether there are obstacles that interfere with getting to action. Efforts to support reflection could involve being clear about the importance of identifying action and even eliciting action (such as through questions like, “what could you do differently next time”). It is also possible that efforts to support reflection might involve monitoring for undesirable actions (e.g., “I’m never going to do that again” or “I’m going to quit,”) and helping students with such actions re-engage in reflective thinking to explore alternative actions.

Intentional: In our framework for characterizing reflection, we highlight reflection as an intentional process. In fact, as we noted earlier, people are always assigning meaning to experience—assigning meaning in an intentional way is what we describe as reflective thinking. In terms of studying reflection, it is interesting to explore questions such as: what role does intentional reflective thinking have in engineering student life, what obstacles interfere with such intentional thinking, and what strategies do some engineering students employ in order to make time for reflective thinking. Efforts to support reflection may involve efforts to help students make time for reflection, stay engaged in reflective thinking when other matters are pressing, and deal with challenges associated with reflection when it might be easier to let less intentional processes take over.

Dialectical. In our framework for characterizing reflection, we highlight reflection as a dialectical process in order to highlight the tensions between using an existing lens to make meaning of an experience and finding that an experience drives a reconsideration of the lens itself. Efforts to study reflection could explore the over-time character of such a dialectical process (i.e., the trajectory of particular reflective thinking accounts). Efforts to support reflection could include acknowledging the complexity of such dialectical processes, prompting a student through such a process, and providing examples of how other students have gone through such processes.

The above critical analysis lays out initial ideas for efforts to study and support reflection. Next steps could include identifying specific research studies and designing specific support strategies. Another area for future work would consist of documenting how engineering students and engineering educators react to the general issue of reflection in engineering education. In the next section, we unpack this latter issue, speculating on the reflection-related concerns educators may raise and what such concerns might mean.

Anticipating challenges in promoting reflection in engineering education

In our experience as educators and researchers, we’ve encountered a range of concerns about why reflection is challenging. Consider the following questions as types of questions that are raised when the subject of reflection is introduced. The questions are listed in no particular order.

- How will I handle it if the students will all go off in different directions?
- What happens if they start to question everything?
- What if something comes up that I cannot handle?

- How do you grade a reflection activity?
- Do reflection activities really work?
- Is there a way of supporting reflection that doesn't interrupt the flow of class?
- Aren't the students simply going to write what I want to hear?
- Is this an evidence-based practice? Where is the evidence that reflection really works?
- Won't students hate it? I think that engineering students don't like to reflect.
- How can I make time for this when there is already so little time?
- Is focusing on reflection the best use of time?
- Don't the students already do reflection in their other classes?
- What will I do if students claim to be experiencing "reflection fatigue" (i.e., report being tired of being asked to reflect)?
- Is there really something for students to reflect on in this class since this class is focused on content and skills?
- How do I know it will work this time since it didn't work the last time I tried it?
- How much effort with this take for me?
- What if I cannot close the loop on issues that they bring up?
- What if the students come to inappropriate conclusions?
- Isn't reflection something that is more important for students in the humanities than students in engineering?
- How will I explain it the other engineering faculty?
- What if the students bring up uncomfortable maybe even personal subjects?
- What if I don't want to be responsible for supporting reflection?
- What if I don't believe in the value of reflection?
- Will I get labeled in a strange way if I try something related to reflection?

When we look across these different concerns, it is possible to see themes. For example, some of the concerns seem pragmatic in nature, such as concerns about time and basic challenges. Some of the concerns seem a more fundamental in nature, such as the concerns about whether teachers are really responsible for student thinking at this level. Some of the concerns also seem to suggest something more critical in nature. We believe that an important critical issue has to do with epistemology, specifically that the kind of knowing involved in reflection (a subjective, integrated, and inferential kind of knowing). This kind of knowing is very different from the kind of knowing commonly highlighted as important for engineering (an objective, linear, and controlled kind of knowing). Efforts to study and support reflection might involve validating the above set of concerns, gauging the prevalence of these concerns, and, in particular, unpacking and exploring the hypothesis that epistemological issues are a central concern.

Conclusion

Our goal has been to provide resources for efforts to study and/or support reflection on experience in engineering education. We started by presenting a framework for talking about reflection on experience. We subsequently discussed various theoretical perspectives on reflection that inspired the framework we presented. In order to illustrate scholarly efforts to support reflection, we provided examples of work across disciplines (such as teacher education,

nursing, medicine, and higher education) as well as work in engineering education. Finally, we discussed how our reflection framework could be used to think about ways to study and support reflection.

We live in a world of high expectations. We are expected to deeply understand who we are, what we believe, and how we interact with others. Coming to such understanding involves reflection. In engineering, with the increasing emphasis on large-scale grand challenges, people-oriented issues, rapidly changing work contexts, and lifelong learning, reflection has become even more important. We anticipate that the ideas presented in this paper will assist researchers and educators interested in reflection—specifically helping researchers with conceptualizing reflection and imagining research studies and helping educators with developing and deploying supports for this important form of thinking.

Bibliography

1. Dewey, J. (1933). *How we think*. Boston, MA: D.C. Heath & Co.
2. Dewey, J. 2009. *Democracy and education*. Seattle, WA: CreateSpace.
3. Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.
4. Schon, D. A. (1984). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.
5. Mezirow, J. (1995). Transformation theory of adult learning. In M. R. Welton (Ed.), *In defense of the lifeworld: Critical perspectives on adult learning*. New York, NY: SUNY Press.
6. Brookfield, S.D. (1995). *Becoming a critically reflective teacher*. San Francisco, CA: Jossey-Bass.
7. Fenwick, T. J. (2001). *Experiential learning: A theoretical critique from five perspectives*. Columbus, OH: ERIC Clearinghouse on Adult, Career and Vocational Education.
8. Kilgore, D., Sattler, B., & Turns, J. (2013). From fragmentation to continuity: Engineering students' narratives about the benefits of developing a professional portfolio. *Studies in Higher Education*, 38(6), 807-826.
9. Dervin, B. (1983). An overview of sense-making research: Concepts, methods and results. Paper presented at the annual meeting of the *International Communication Association*. Dallas, TX.
10. Dervin, B. (1992). From the mind's eye of the user: The sense-making qualitative-quantitative methodology. In Glazier, J. and Powell, R. R. *Qualitative research in information management* (p. 61-84). Englewood, CA: Libraries Unlimited.
11. Dervin, B. (1996). Given a context by any other name: Methodological tools for taming the unruly beast. Keynote paper, *ISIC 96: Information Seeking in Context*.
12. Weick, K. (1979). *The Social Psychology of Organizing*. New York, NY: McGraw-Hill.
13. Argyris, C., & Schön, D.A. (1978). *Organizational Learning: a Theory of Action Perspective*. Reading,

MA: Addison-Wesley.

14. Piaget, J. (1983). "Piaget's Theory". In P. Mussen (Ed.) *Handbook of child psychology*. New York, NY: Wiley.
15. Metcalfe, J., & Shimamura, A. P. (1994). *Metacognition: Knowing about Knowing*. Cambridge, MA: MIT Press.
16. Kaplan, M., Silver, N., Lavaque-Manty, D., & Meizlish, D. (2013). *Using reflection and metacognition to improve student learning: Across the disciplines, across the academy*. Sterling, VA: Stylus Publishing.
17. Lyons, N.P. (Ed.). (2010). *Handbook of Reflection and Reflective Inquiry: Mapping a Way of Knowing for Professional Reflective Inquiry*. New York, NY: Springer.
18. Mann, K., Gordon, J., & MacLeod, A. (2009). Reflection and reflective practice in health professions education: A systematic review. *Advances in Health Sciences Education*, 14(4), 595-621.
19. Bennett-Levy, J., & Padesky, C. (2013, in press). Use it or lose it: Postworkshop reflection enhances learning and utilization of CBT skills. *Cognitive and Behavioral Practice*.
20. Russell, B. H., Geist, M. M., & Maffett, J. H. (2013). SAFETY: An Integrated Clinical Reasoning and Reflection Framework for Undergraduate Nursing Students. *Journal of Nursing Education*, 52(1), 59-62.
21. Back, J., Furniss, D., Attfield, S., Hassard, S., and Blandford, A. (2009). Exploring the importance of reflection in the control room. In *Proceedings of the CHI annual conference*.
22. Brown, T. J. (2009). Self-informatics: Considerations for designing technology which supports user. In *Proceedings of the CHI annual conference*.
23. Fleck, R. (2009). Supporting reflection on experience with SenseCam. In *Proceedings of the CHI annual conference*.
24. Lindley, S. E., Randall, D., Glancy, M., Smyth, N., & Harper, R. (2009). Reflecting on oneself and on others: Multiple perspectives via SenseCam. In *Proceedings of the CHI annual conference*.
25. Morris, R. (2009). Supporting collaboration and reflection with digital tabletops. In *Proceedings of the CHI annual conference*.
26. Raybourn, E. (2009). Intercultural competence game-based training that fosters reflection. In *Proceedings of the CHI annual conference*.
27. Eliot, M. (2009). Toward the ideal self: Investigating potential technologies for self-improvement. In *Proceedings of the CHI annual conference*.
28. Bateman, S., Teevan, J., & White, R. W. (2012). The search dashboard: How reflection and comparison impact search behavior. In *Proceedings of the ACM Human Factors in Computing Systems annual conference*.
29. Grimes, A., Tan, D., & Morris, D. (2009). Toward Technologies that Support Family Reflections on Health. In *Proceedings of ACM GROUP 2009 conference*.
30. Ambrose, S. A. (2013). Undergraduate engineering curriculum: The ultimate design challenge. *The Bridge: Linking Engineering and Society*, 43(2), 16-23.

31. Walther, J., Sochacka, N. W., & Kellam, N. N. (2011). Emotional indicators as a way to initiate student reflection in engineering programs. In *Proceedings of the ASEE annual conference*.
32. Hirsch, P. L. & McKenna, A. F. (2008). Using reflection to promote teamwork understanding in engineering design education. *International Journal of Engineering Education*, 24(2), 377-385.
33. McKenna, A. F., Yalvac, B., & Light, G. J. (2008). The role of collaborative reflection on shaping engineering faculty teaching approaches. *Journal of Engineering Education*, 97(1), 17-26.
34. Kavanagh, L. & O'Moore, L. (2008). Reflecting on Reflection – 10 years, Engineering, and UQ. In *Proceedings of the Austral-Asian Engineering Education (AAEE) annual conference*.
35. Turns, J., Newstetter, W., Allen, J. K., & Mistree, F. (1997). Learning Essays and the Reflective Learner: Supporting Reflection in Engineering Design Education. In *Proceedings of the ASEE annual conference*.