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Developing and Assessing Students' Ability to Engage in Lifelong Learning*

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Many modes and definitions of learning ensure that learning will not be lifelong, cultivating a dependence on the expertise of a faculty member who 'downloads' knowledge to students without much interaction or negotiation in the learning process. By fundamentally altering the way we understand learning from something that is to be remembered to something that is to be engaged with, empowering students to be responsible, self-directed and intentional learners and creating a new, question-centered process, we can open up new possibilities for lifelong learning in which assessment becomes integrated as an inherent part of the learning process and not simply something that comes at the end to measure learning.

Keywords: lifelong learning; blogs; reflection; relational learning; self and integrated assessment; liberative pedagogies.

INTRODUCTION

MANY TRADITIONAL MODES and definitions of learning ensure that learning will not be lifelong, cultivating a dependence on the expertise of a faculty member who 'downloads' knowledge to students. Freire's [1] critique of the 'banking system' of education describes exactly this phenomenon: 'knowledge is a gift bestowed by those who consider themselves knowledgeable upon those whom they consider to know nothing'. Clearly such an approach to learning requires that students be dependent upon a teacher, and indeed an institution of learning, for the acquisition of knowledge. Students' ability to engage in lifelong learning improves when their independence grows and their ability to ask critical questions deepens.

By fundamentally altering the way we understand learning, empowering students to be responsible, self-directed, intentional learners, and creating a new, question-centered process, we can open up new possibilities for lifelong learning.

WHAT IS LIFELONG LEARNING?

The conventional wisdom among engineering educators is that lifelong learning is a fuzzy concept, difficult to define and even more difficult to measure. On one level, as Knapper and Cropley [2] suggest, the concept is quite easy to articulate and simple to grasp: 'Deliberate learning can and should occur throughout each person's lifetime'. Yet there are significant debates in the education literature about what lifelong learning is and how to approach it. Here we review some key discussions about lifelong learning in the literature, and develop our own approach grounded in liberative pedagogies [3–5].

Lifelong learning as a neoliberal tool for social control

In the United Kingdom, lifelong learning has a meaning strongly associated with building a competitive labor market in a globalized context. In a UK government research brief, Raggatt *et al.* [6] identify lifelong learning as a way to help employees stay competitive in labor markets that are uncertain due to economic, technical, and social changes. They note that some question such a market-based, individualized approach, because it will lead to unequal access to education and may not meet national needs for education and training, especially considering the increase in demand for unskilled labor. Moreover, such an individualized approach in the context of a global labor market amounts to neoliberalism [7], a political trend that underlies globalization, opposing any restrictions on industry and trade, union organizing, government provision of social services or public goods, relying on 'trickle down' economic theories to lift up the poor.

Coffield [8] articulates how this approach is a means of social control. Lifelong learning becomes a site of conflict among employers, unions, and the state, wherein 'empowerment' is used to encourage employees to take on greater workloads in times of downsizing, 'employability' masks a retreat from government commitment to combat unemployment or support those who are temporarily unemployed, and 'flexibility' masks cost-reduction strategies that ultimately put more jobs at risk. A critical approach to lifelong learning must keep these larger economic trends in perspective and

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always ask who benefits and who loses. The engineering community would be wise to anticipate the impacts of this approach to lifelong learning on the profession and on the quality of engineering careers.

Olssen [7] suggests a way forward: 'Although [lifelong learning] has manifested a uniformly consistent—albeit not exclusive—concern of serving dominant economic interests, the prospects for moving beyond it depend, I argue, on whether the structures of learning created can be harnessed for other ends; that is, whether embryonic within the discursive programme of lifelong learning is the possibility of linking the discourse to a progressive emancipatory project based upon egalitarian politics and social justice'. This is precisely what a liberative pedagogies perspective on lifelong learning seeks to accomplish.

Lifelong learning as adult, continuing, or distance education

In the United States, lifelong learning is largely cast as adult, continuing, or distance education, and when examined closely, education policy discussions reflect similar political undertones to those in the United Kingdom. For example, Hardi [9] writes in the *Chronicle of Higher Education* about a land-grant university commission's report that sought to promote lifelong learning as a means to prepare the workforce of the future. Here the lifelong character of learning is interpreted to mean that those who cannot afford higher education while they are 18–22 could, with the aid of tax incentives, save up for higher education later in life. Similarly, the House Subcommittee on Postsecondary Education, Training, and Life-Long Learning emphasized lifelong learning as a means for retraining individuals into 'better' jobs in contexts such as Welfare Reform [10].

Many institutions use the label 'lifelong learning' for their adult, continuing, or distance education programs. ABET's own industry advisory council defines lifelong learning as 'the process of acquiring the skills and knowledge necessary to remain current in a chosen field', but then equates this with formal continuing education: 'Lifelong learning covers a broad spectrum of continuing education options, including short courses, professional society meetings, and graduate degree programs' [11]. Following suit, many engineering programs simply track their alumni involvement in continuing education as a measure of lifelong learning.

However, we assert that this should not be what ABET means by lifelong learning. Presumably students graduating with an undergraduate degree in engineering already have the ability to enroll in online courses or adult or continuing education classes at community colleges and public or private universities, and their success in formal undergraduate education itself would easily demonstrate this ability. Moreover, measuring the percentage of students who pursue formal continuing education is not a measure of the ability to engage in lifelong learning at the time of graduation, as the ABET criterion requires. Briedis [12] points out that these measures do not evaluate the specific skills and behaviors that underlie the outcome and thus cannot be used effectively in an upward spiral process of improvement.

Lifelong learning as self-directed learning

ABET's criterion for lifelong learning (in which programs must demonstrate that students attain 'a recognition of the need for, and an ability to engage in lifelong learning') [13] ought to refer to a broader definition in which students are able to identify goals for learning, assess their learning progress, and make changes in their learning to improve their progress toward their goals. This process is known as self-directed learning, and constitutes the fundamental skill set for lifelong learning. Candy [14] presents a view of lifelong learning as self-directed.

Knapper and Cropley [2] discuss lifelong learning in the context of traditional institutions of higher education, and argue that the role of colleges and universities is to prepare students for lifelong learning. To that end, upon graduation, Knapper and Cropley suggest that students should be active learners who are able to plan and assess their own learning, learn in formal and informal settings, from peers and teachers alike, integrate knowledge across disciplines and across curricular and co-curricular activities, and use different learning strategies in different contexts. Thus the ABET criterion on lifelong learning is different from the others in that it is specifying a process more than a learning outcome.

Lifelong learning as liberation

Finally, we propose that in addition to lifelong learning possessing all of the characteristics of self-directed learning, it should serve a social purpose related to liberation. Specifically, Freire [1] identifies two key capacities that are outcomes of liberative pedagogies: critical thinking and reflective action (praxis). Each of these is essential to lifelong learning. Lifelong learners think critically about their life situations and goals, and reflect deeply about where they are and where they want to go. Following this reflection, lifelong learners also take action, linking intellectual processes with personal transformation and change in the world. Such action is liberative, both of the individual through personal transformation, and of some segment of society through the reflective action of learners.

Liberative pedagogies emphasize the authority of experience in a move toward leveling power dynamics between learners and teachers. Thus, in classroom settings, students practice lifelong learning with the facilitation of the instructor, who provides feedback and guides student development. Student responsibility for learning and parti-

cipation in self and peer assessment is emphasized. Learning is active and student centered, and often cooperative and inquiry-, problem-, or community-based. Learning is both integrative and relational. All of these are key characteristics of lifelong learning, resulting in the ability to think creatively and act in response.

Why does ABET include lifelong learning in its criteria?

At the ABET Assessment symposium in Terre Haute in 2006, participants in the lifelong learning workshop suggested the following reasons for the inclusion of lifelong learning as an ABET criterion:

- Self-directed learning is directly related to problem-solving ability. Learning independently and being able to self-manage learning is critical for successful individual problem solving.
- Team building—Self-directed learning builds better teams, so that students can tackle open-ended problems as individuals and as valuable members of a team.
- Like the industry advisory board argument, technology changes rapidly, and engineers need to be able to adapt and acquire new knowledge and skills as times demand. Adaptability.
- Graduate school/Research preparation—lifelong learning skills are research skills, and some portion of our graduates will pursue higher degrees and conduct research.
- The overcrowded nature of the engineering curriculum necessitates it. That is, without being able to learn in a self-directed way, students would not be able to learn everything they need to know to practice engineering in four years.
- As educators, we are committed (and our institutions are committed) to develop a whole student, who is also a citizen, and member of a local and the global community. Lifelong learning ought to help students continue learning in contexts outside of engineering that relate to other aspects of individual or community development.
- Self-directed and lifelong learning is essential for self-knowledge, which is required for students to develop internal motivation for lifelong learning, and for students to develop a sense of ethics.

It is apparent from this brainstorming that the community of engineering educators (and likely some subset of ABET site evaluators) think of lifelong learning in multiple senses, which require both self-directed and liberative learning.

What does it take to engage in lifelong learning?

Costa and Kallick [15] describe self-directed learning as a continual feedback spiral of:

- self-managing (in which students articulate their own learning goals);
- self-monitoring (in which students assess their achievement);
- self-modifying (in which students make mid-course corrections).

Learning and assessment are naturally connected here, because a good learning process requires continual assessment. Liberative pedagogies require that students be involved in assessment as equal participants in the learning process.

These processes, in which students learn, exercise, and assess lifelong learning skills require the following:

1. Questioning, curiosity, data gathering.
2. Independence and innovation.
3. Relationality (interdependence) and communication.
4. Metacognition.
5. Critical thinking and reflective action.
6. Character—self-knowledge, persistence, values.
7. Motivation.

The unifying thread here has to do with one essential goal, which in a sense is a double one: to get students to the high order thinking level of asking a deceptively simple question: 'why?' Both the goal of getting students to ask why, and the interconnected goal of faculty engaging with the assessing why students ask why is directly related to the seven points listed above for lifelong learning to be taking root.

First, students are not really questioning or curious until they are themselves motivated to ask *why*. When students come to ask why, they are suddenly more deeply invested in not only what they are studying but also how they are engaging with the subject matter at hand, thus beginning a learning process that is the practice of freedom. [16] Indeed, the moment students come to be asking why questions they are starting to liberate themselves from alienated motivation that typically makes sure that something is learned for now but too often quickly forgotten. Such alienated motivation can be identified in the very discourse students use in, such often used phrases as 'because I have to' or 'because I want to get a good grade'. There is not necessarily anything wrong with wanting to get a good grade. However, motivation can become undermined and then alienated if in the process of seeking a good grade one loses sight of what it is within one's self that motivates one's own curiosity and questions. Cramming can take the place of learning when the 'why', one's motivation for learning, has not been taken fully into account.

Second, students are not really independent or innovating if they are not asking what constitutes the deeper questions to them, which are invariably directly related to 'why' because as we just saw 'what' and 'how' is motivated by why. Students who start relating the material to their life, being able to ask their own questions about it, engaging these to why, do not only become more independent and engaged thinkers, but these questions also lead them to innovate in their learning because

they start asking their own questions and doing so in the way that best fits who they are as a learner. They are making the material theirs.

Third, while it is true that students who are encouraged and guided to ask *why* become more independent, it is equally so and not contradictory that the pedagogic relationship and the kind of communication they have with their faculty is instrumental in the development and facilitation of asking why, of asking questions that will remain alive for life, indeed, for lifelong learning [17]. Lifelong learning can be seen as something that is instilled more than something to just learn as in committing to memory. Lifelong learning is a process. Clearly, however, lifelong learning does not do away with content, but it is not motivated by it. Lifelong learning is motivated by both making this content ours and furthering it as well.

Fourth, metacognition or students thinking about their thinking and learning is something that is not only encouraged by asking why but it is a key component and benefit of it [18]. 'Indeed, when students are encouraged to ask why they not only turn outward and ask why things are the way they are, but in fact, in order for them to do so they must first turn inward and ask themselves what, how and why they are learning what they are learning—how does it make sense to them.'

Fifth, as a natural progression from metacognition comes critical thinking and reflective action [1]. By asking why students become critical thinkers who do not simply believe what they are told. This does not mean that they simply reject it, because this would mean that they are asking *why* simply for the sake of asking why without having it linked to their own life, thinking and aspirations. Students who authentically ask why learn the material and keep it inside as something meaningful because asking why allows them to create a personal connection to the material which is evidently pivotal to lifelong learning. Once students are clearly thinking critically about the subject matter, we see that they want to do something about it and this is when reflective action happens.

Sixth and seventh, character, self-knowledge, persistence, values and motivation are inextricably linked to the asking of why in that they all need the element of personal involvement, personal curiosity and personal drive that we have seen why makes possible.

If we believe that do not really teach students anything until they come to ask why, then the dual goal of students asking why as faculty also engage students with why questions comes into clear focus. It is when they ask 'why' authentically, or if you will existentially, that they are committed to the 'what' and 'how' of their learning. The 'what' and 'how' make full sense only in relation to the 'why'. In addition, it only follows that we cannot assess students' engagement and thus lifelong learning until we as educators know why they are asking why questions. Becoming familiar with what motivates students to ask why and how they ask why can give us key information as to whether and the extent to which students are becoming lifelong learners. The more students link the material they study to their existential self by authentically asking *why*, the clearer it is that they are becoming lifelong learners—why questions can take a lifetime to answer, and these are the questions that will lead them all the way.

In summary what we are describing here is an intentional learning process that builds beliefs about and attitudes toward learning, motivation to engage in lifelong learning, and finally critical thinking and reflective action that provides feedback to the process. As we have seen, however, this does not mean that it is independent of faculty input and feedback; one of the key factors being in fact interdependence. This is because this learning process is one in which the faculty facilitates the learning more than say teaching to the test. On the one hand there is more freedom on the part of the students to explore and ask questions, but on the other this gives students more responsibility for learning, even as that responsibility is shared with faculty.

DEVELOPMENT OF LIFELONG LEARNING ABILITIES

When taking a liberative approach to learning, or any student-centered approach, the development and assessment of lifelong learning skills go hand in hand, and assessment becomes a learning tool. Students actively participate in practicing and assessing those skills, and self and peer assessment is as important as instructor assessment.

Because lifelong learning skills and learning with liberative pedagogies are process-oriented, it is critical that processes are assessed as well as outcomes. The learning process is itself the means to ensure achievement of outcomes. Learning processes should simultaneously measure and facilitate student learning, encourage self-assessment and metacognition, invite and document reflection, questions and critical thinking, and increase abilities to engage in lifelong learning. In this way, assessment is itself a motivator that supports lifelong learning.

Because abilities for lifelong learning require metacognition and personal ethical development, among other things, the ability to reflect meaningfully and act upon that reflection is absolutely central. Assessment must therefore allow for who the student is as a learner, what s/he brings through life experience, and document and assess reflection that increases in quality over time. This reflective component might be measured more qualitatively, while other aspects of the abilities for lifelong learning might be more quantifiable. As the assessment goes back and forth between quantitative to qualitative, it models the integration of knowledge from the sciences with the humanities and social sciences in engineering, link-

ing to ethics and social justice concerns. This kind of integrated thinking is identified as one of the lifelong learning skills by Knapper and Cropley [2]; it should be practiced, documented and assessed in an integrated fashion. Assessment is not only integrated with learning, it is an ongoing and continuous process that is intertwined with learning throughout a course.

Lifelong learning, when practiced in an integrated way that is connected with *praxis*, the reflective action that is the goal of Freirian pedagogy, has wide-reaching implications. If students can engage engineering thought in a liberative way, with an eye to lifelong learning, they can create a space for questioning and information that go beyond the classroom, releasing a great potential for reflective action and social change. Below are ten practical ways engineering programs can promote the development of lifelong learning:

1. Model lifelong learning with teaching, and with ABET processes. Good teaching requires that faculty be self-managing, self-monitoring, and self-modifying. Indeed many faculty members are self-directed learners by nature of being researchers. If a program truly embraces ABET processes and internalizes the principles of assessment, these should also model self-directed learning (self-managing, self-monitoring and self-modifying). Making these processes transparent to students (and indeed involving students where appropriate) can model self-directed learning for them.
2. Use learning methods and classroom activities that support lifelong learning. Felder and Brent [19] note that approaches including active and cooperative learning, problem-based, inquiry-based, and project-based learning can support the development of lifelong learning abilities. Parkinson [20] additionally discusses the importance of design as a lifelong learning development activity.
3. Build in opportunities for reflection, meta-cognition, and self-directed learning. Students need time and guidance to develop lifelong learning abilities. These should therefore become an explicit focus in the classroom, with adequate time and feedback allotted to them. Teaching about learning is essential not only for students to engage with what may be unfamiliar pedagogical practice or classroom activities, but also for students to develop fundamental skills in reflection and meta-cognition. Felder and Brent [19] suggest incorporating the Index of Learning Styles to create these opportunities. Below we suggest blogging as another tool for accomplishing this goal.
4. Ask students to critique the syllabus and/or learning objectives. A sample assignment used in an upper level mass and heat transfer class is provided in Fig. 1. This made self-directed learning explicit, and was an extremely popular element based on course surveys. In conjunction with this approach students developed a portfolio documenting their achievement of learning objectives, and reflecting on the learning process.
5. Give clear and frequent feedback with opportunities to iterate. Learning and assessment are connected through feedback provided to students. Rubrics and other types of feedback scales can communicate clear expectations to students, give students structured opportunities for self- and peer-assessment, and give crucial instructor feedback on ways to improve. Practical examples of rubrics can be found in Wiggins and McTighe [21] and Huba and Freed [22]. Critical thinking can be an especially difficult area, because the word is used so frequently but is so rarely defined. The Foundation for Critical Thinking [23] has useful resources on defining and evaluating critical thinking. Finally, Parkinson [20] suggests considering grading based on competency. McNeill [24] describes a learner-centered approach for evaluating student work employed in an engineering program that is compatible with, but takes some focus off of, traditional grading.
6. Portfolios can be an important way to incorporate lifelong learning skills, because, when implemented well, they embed self-directed learning skills such as articulating learning objectives, assessing how and to what extent those objectives have been met, and reflecting on how to improve targeted skills in the future. Rose-Hulman Institute of Technology has implemented electronic portfolios for assessment across the campus [25].
7. Support relationality and learning communities. As students increase their capacity for independent learning, they also need to see the value of interdependence, and in particular the role of peers in providing important feedback and support in learning. Teamwork, and other kinds of collaborative learning, when structured well, can support this goal [19].
8. Research and information literacy. Others have noted the importance of information literacy skills [12, 19, 20] in developing the ability to engage in lifelong learning. Practicing the identification and evaluation of information either in classroom contexts, and ultimately in actual research, benefits students greatly in acquiring independent learning. Research itself should also aid in the development of good questions, certain types of critical thinking skills, and when practiced in a supportive community, relationality.
9. Build interconnections to other disciplines, co-curricular activities, and student lives. Lifelong learners are highly motivated because they see the relevance of learning to their personal and professional lives [20]. Relating learning in engineering to other courses, to co-curricular activities, and to student lives make this rele-

Proposal for Self-Directed Learning
EGR 363
Mass and Heat Transfer
Prof. Donna Riley
Smith College
Fall 2005

You will have the freedom and responsibility to determine your own course of learning collectively and individually, based on your interests and schedule. Your proposal of 3–5 pages shall include:

a. Background information on why you are choosing to take this class and what you hope to get out of it—how it relates to your development as an engineer, and as a whole person, and how it relates to your overarching educational goals. (There are big questions here—why are you pursuing a bachelor's degree? At a liberal arts college? In engineering? How does each of these choices relate to who you are, who you seek to become, and the values you hold?)
b. A list of objectives, including the objectives above (you may suggest changes to these), plus 1–3 additional objectives you wish to set for your learning in this class.
c. A list of topics you would like to cover in order to meet the complete list of objectives, and a course map of how these topics relate to the objectives.
d. A list of resources. These might include people, readings, films—anything or anyone that supports your learning. It is not possible to provide a complete or specific list of these at this point, but you should provide suggestions and examples of the types of resources you would like to include. For example, heat transfer has come up in the news in (at least) two ways this summer—with the space shuttle, and with the giant popsicle meltdown in NYC when they were trying to set a world record—what a mess!
e. A work schedule for time spent inside and outside of class, by topic of interest, as well as suggested readings, class activities, and assignments. You do not have to plan everything out, but some ideas about how you would like to spend your time is key. You may use the syllabus here as a guide but a complete departure is welcome too—the intent is to design something to suit your needs and interests. Be clear about what you propose to do and what you ask of others.
f. A plan for evaluating and assessing how you meet the learning objectives. How is this best measured? From whom would you like to receive feedback? Of what type, and how frequently? What does it mean to learn the material? What is the right balance between quality and quantity, breadth and depth, product and process? Which course elements should be graded (if any), and at what weights?

Although the initial due date for this proposal is September 13, you may revise it throughout the semester as needed and until full credit is earned.

Fig. 1. Proposal for self-directed learning, mass and heat transfer, Smith College.

vance come alive. It is important to recognize the connection-building and interdisciplinary thinking as a skill in itself that enables students to learn and get excited about new things.

10. Elicit the why of why. When students can articulate why they want to know why, instructors can get at the basis of their motivation for inquiry, and their motivation for learning. This elicitation can happen through formal reflective exercises or informally during class or office hours. Taking the time to show interest in students and what motivates them is a relational act that can help students unlock their own excitement about a course or subject matter and ultimately can engender a passion for lifelong learning.

ASSESSMENT OF LIFELONG LEARNING ABILITIES

Conventional assessment

Some elements of lifelong learning can be assessed using out of the box measures. We present a review of these below. We recommend their use in conjunction with more liberative approaches. It is tempting to use these tools alone because they are standardized and ready to use, but we caution that they are not likely to give a complete assessment of lifelong learning because they measure only certain aspects of readiness to engage in, or attitudes toward, lifelong learning.

The Self-Directed Learning Readiness Scale (SDLRS) [26] is a widely used and validated tool with a long history and literature supporting it. While focused on readiness for self-directed learning, the scale has been used in engineering contexts both to teach [27] and to assess [28] lifelong learning abilities. Costa and Kallick [15] provide additional extremely practical tools for developing and assessing self-directed learning abilities in students, including surveys, rubrics, and classroom activities.

Briedis [12] offers a list of performance indicators for lifelong learning, including:

(a) information literacy to support independent learning;
(b) ability to navigate professional and technical support systems such as professional societies and professional registration systems;
(c) an awareness of the changing nature of science and engineering;
(d) the ability to learn independently.

To meet each of these, she suggests:

(a) offering problems that require students to analyze, synthesize, and evaluate information;
(b) conducting discussions of the professional support systems available to graduating engineers;
(c) providing examples of changing principles or technologies from the history of science and engineering;
(d) completing a project that requires independent learning and the use of information literacy tools. Rubrics follow that allow for the measurement of these performance indicators.

A few reports from engineering programs record practical experience to date in measuring lifelong learning. Marra [29] presents a review of instruments from the education literature specifically addressing lifelong learning, observing that results are inconclusive for these instruments and that there is some overlap with the self-directed learning instruments. A multistep plan for assessing lifelong learning in engineering is presented that combines a curricular review, student surveys that measure meta-cognitive aspects of lifelong learning, and some of the existing lifelong learning instruments. Mourtos [30] presents a detailed approach for engineering course design and assessment for lifelong learning. A combination of student performance and student survey results is then used to measure lifelong learning across the curriculum.

In addition, Felder and Brent [31] review two areas in which one might assess ability to engage in lifelong learning—the approaches to learning literature and the intellectual development area. Using these scales might be problematic in assessing student readiness to engage in lifelong learning, but one approach might be to focus on the 'delta'—the amount of change in student approaches to learning or level of intellectual development when they enter and leave an engineering program. It is unlikely that all students would meet a desired level of intellectual development or adopt a deep approach to learning, but a program that promotes intellectual growth and that facilitates student adoption of deep approaches would promote lifelong learning in students. Such scales are likely to provide helpful contextual information about where students are that would facilitate the development of a plan to help students prepare for lifelong learning.

Learning-integrated assessment through blogging/ journaling

Riley *et al*. [32] present a tool for enhancing and assessing lifelong learning abilities that utilizes a web journal or blog, to document the student learning and self-assessment process. Journaling can encourage student reflection and enable students to connect classroom content with personal experience. Blogs make the journaling experience interactive, giving students continuous access to their own reflections and those of their peers.

The blog creates space for students to bring themselves into the classroom, equipped with reflective insight and prepared to actively engage in classroom learning. It provides an alternative means of student motivation, another entry point into the subject matter by connecting with what students find relevant. It encourages metacognitive reflection and promotes student responsibility for learning. It creates a more inclusive intellectual community by allowing free exploration of new thought, while at the same time giving students access to each others' ideas. It promotes interaction and relationality, enabling a continuing conversation outside of class, as instructors and peers respond to blog entries. It engages students in creating meaning by situating themselves and their knowledge not only in the classroom but also in the world. This can have a profound impact on student interest, motivation, and performance, and of course on lifelong learning.

The blog is not only a learning tool, but also an assessment tool. It provides a progression of student development and idea development through time. It enables instructors to see each individual student's progress and to compare progress across students, providing an important insight into student learning and thinking. It provides instructors with personal context and information about student preconceptions, which can then be addressed in class. Most important, it provides significant data documenting the development of student ability to engage in lifelong learning over time.

We used blogs in an engineering thermodynamics class to measure and enhance student learning. The blogs were graded and amounted to 10 percent of the course grade. The blogs were integrated into other course assignments from problem sets, to group projects, to ethics case analyses. The instructor also connected blogs to day-to-day in-class learning, utilizing student questions. A group project geared toward reflective action grew out of the blogs, creating a community within the class that read each other's blogs, and a connection to the broader community through the students' projects, modeled after Catalano's compassion practicum [33].

Description: students create entries in response to guiding questions, which should take about 30 minutes once every week or two. Following a blog format, each entry appends to the last, so that an entire semester's development is displayed on a single page. Before a new topic is introduced, students reflect on a question that helps them articulate their knowledge and experience related to the course material about to be presented. After material is covered, students reflect on what they learned and its relationship to other aspects of their lives. Questions are central, developing critical thinking skills. Community interaction occurs when students read each other's blogs, and as the blogs are discussed in class. Students independently explore questions of their choosing. Instructor blogging enhances community and is used to help demystify the instructor's approach to student learning, and encourage meta-cognitive reflection.

The blog employs an inquiry-based methodology [34], addressing three challenge levels:

- Articulate questions in the learning community
  - Instructor can identify preconceptions to build on or correct in class
  - Student can often answer questions independently, or with peers
  - Student can assess her own understanding and think ahead

  - Student can establish ownership of material and reflect in a deeper way
- Independent exploration of questions
  - Student has the opportunity to practice self-directed learning
  - Student reflects and engages meta-cognitively about learning, assessing her experience to date
  - Student can explore her own interests and find how they relate to the course material
- Transfer of knowledge to reflective practice
  - This connects blogging with classroom learning and with its real-world applications
  - Student reflection and critical thinking leads to positive action, often also relating to concerns discussed in class around ethics and social justice.

Examples of blogging

A full discussion of student blog work can be found in Riley *et al.* [32]. Some relevant blog excerpts for lifelong learning include examples of students relating material to other disciplines, thinking critically, and acting reflectively. One student related thermodynamics to her previous experience with learning circuits:

> I was very interested by the problem and chart in the book that talked about the error in assuming water vapor is an ideal gas. It would be interesting to look at other gases and determine the errors in assuming that they are ideal gases. It is always a good exercise to think about how the ideal case differs from an actual case because the real world is often not ideal. I have especially found this to be true in circuit analysis. Although there are great analysis techniques for simple, ''perfect'' circuits, these do not always work for real circuits like those that I encountered during my internship.

Another student thought critically about assigned textbook problems on the thermodynamics of biological systems:

> I must make a few comments regarding the exercise problem in our homework. I was a bit disconcerted to see a problem that had someone lose 5kg in 13 days. It is recommended that a person only lose up to 2 lb per week, .9 kg, or 1.68 kg for 13 days.... I realize that this is only a book problem, and that book problems are not suppose[d] to have any bearings on real life. Still, it would be nice if a book at least did not use highly unhealthy behavior as an example without some commentary.

This critical thinking led the same student to reflective action (though she minimizes its importance to some extent in her description), building connections and addressing body-image issues with non-engineers:

> I have spent the past week talking to my friends about weight loss with a thermodynamics perspective. I think that it's just because most of my friends have body issues and it's a way to get them to be interested in what I am doing rather than just staring at me when I talk about class. . .

Evaluation and feedback

Student blogs were evaluated using a rubric (see Fig. 2). Many other rubrics are available in Wiggins and McTighe [21] or Huba and Freed [22]. Because learning and assessment are connected, feedback is essential, and student improvement should occur with effective feedback. Riley *et al.* [32] found that some students improved over the semester, but others' blogs declined in quality, perhaps due to increased time pressures from all classes as the semester continued.

The blogs serve as their own evidence and documentation of the capacity for lifelong learning. That is, because student engage in a process of self-management, self-monitoring and self-modification, they demonstrate the capacity of lifelong learning through their participation in the blog. In addition, critical thinking, meta-cognitive reflection, reflective action, connections to other disciplines and to student lives are readily identified and their quality assessed. Because students pose questions and offer personal reflections, the 'why of why' is transparent. When blogs are used within the classroom context, and when students work in teams on reflective action projects, relationality and interdependence are easily demonstrated.

To some degree, feedback is subjective. Therefore, involving students in self- and peer-assessment, and allowing for iterative improvement in a given work can ensure a fair process that clearly communicates expectations, considers multiple perspectives, and gives students multiple opportunities to demonstrate skill development and improvement. Finally, if faculty are self-managing, self-monitoring and self-modifying, this process of feedback in the classroom will also improve over time!

Student feedback on blogs

Riley *et al.* [32] also assessed student learning experiences with the blog using written course evaluations and three focus groups with 14 students total (all students in the course were invited to participate in focus groups, for a response rate of 47 per cent). Among other things, students discussed how the blogs improved their capacities for lifelong learning:

> This program is helping us to be ready for anything and with this class I am more able to relate things to my life. I was taking a shower the other day and I suddenly caught myself wondering if maybe there was no vent in here. I am now able to see more of the beauty of thermo. . .

> The blog . . . made me think, pull knowledge and make connections that I would not have before. Usually I would just have gone to classes and learn about something versus thinking about it and trying to figure it out myself. That made me feel a bit more confident that I could actually do something rather than just learn, I can actually create or come up with something myself rather than learn what people have already done.

> I think that one thing that has changed about how I

Blog Rubric
EGR 290—Engineering Thermodynamics

	1	2	3	4	5
To what extent are the following qualities practiced and achieved?	**Not at all** (fails to engage with the skill at hand)	**Not very much** (manages to engage with the skill but does not show much interest in it)	**A fair amount** (engages with the skill and shows interest)	**Quite a bit** (engages with the skill and is clearly interested and curious)	**A lot** (engages actively with the skill and a manages to make it her own)
Reflection—student is reflecting extensively on the questions and taking them seriously. Values are articulated honestly. Student is referring to her experience, using prior knowledge, as well as experimenting with new knowledge. Connections are made to the course and subject matter at hand, engineering practice, and the student's life. Connections illustrate a solid understanding of the issues.					
Critical Thinking—student asks incisive questions that probe the meaning and implications of the reading. Student articulates new ideas to pursue that go beyond the course material					
Reflective action (praxis)—Student took action that grew from her engagement with the course. Action reflects her personal development (in terms of responsibility or moral imagination), utilizes previously unknown skills and knowledge, and relates to her identity as and engineer in the larger context of the profession and society. Student made a conscious active change whether practical, cognitive-emotional, or both as a result of the insight gained from self-reflection or relational interaction.					

Fig. 2. Rubric for blogs, engineering thermodynamics, Smith College.

> approach problem sets now through this course is that I think before I would just dive into problems and try to solve them right away, whereas now before I even start I take a few minutes to look at the problem and just like really think about it. I ask myself about what I know about the problem. It is interesting to me because I have never done this before until this class—I try to see how it all relates together.
>
> I am more critical; critical about the problems we solve, about the issues we cover in class and the discussions we have there also. There have been so many deep thoughts that have come to me that I don't think I would have had or would have seen things that deeply if I had not taken this thermodynamics class. It was not just the sciences, the technology, and all the math behind it, it was also this other side that helped me develop these critical thinking skills.
>
> To me it was all about becoming an empowered learner and with that you learn how to ask questions that will enable you to learn more about thermo and take the class to the next level.

The one consistent negative associated with the blog was the time it took students to complete it, along with the overall course load. Time invested ranged from 30 minutes a week (per instructor's suggestion) to several hours [32]. Perhaps some students had a hard time letting go of the structure and time requirements typical of formal papers with which they are more familiar.

DISCUSSION AND CONCLUSION

Integrated learning/assessment tools are necessary for developing and documenting lifelong learning abilities in students. Without them, assessment of lifelong learning remains incomplete, and our understanding of lifelong learning itself is incomplete when we do not recognize how the two go hand in hand. Integrated learning/assessment tools are effective because they engage students actively in an exploration of their own learning processes, encourage the formation of questions and critical thinking, stimulate personal, professional, and metacognitive reflection, create connections to other disciplines, co-curricular activities, and students' lives, and motivate students to develop strategies for learning that lasts. The interactive blog format stimulated the creation of a learning community as students offered answers to questions asked by others and inspired one another with their explorations of new ideas.

Blogs are of course only one example of integrated learning/assessment tools for lifelong learning. Portfolios are another excellent example, and we have implemented these with success as well. Both tools can be implemented in any engineering course, and serve multiple functions for teaching, assessment, and documentation of multiple factors

in lifelong learning and other learning objectives as well.

More integrated learning/assessment tools should be identified and developed to provide programs with more options for documentation of self-directed learning processes, along with critical thinking and reflection. A greater variety of tools would be helpful to the engineering education community, so that programs have more flexibility as they design curriculum delivery and assessment strategies.

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