Mirror Mirror: Reflection and the Building of Mindsets

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Introduction
It has been said that entrepreneurship is a contact sport (attributed to Tina Seelig), by which it is meant that entrepreneurs are strongly biased toward action. But many entrepreneurs also wax poetic about continuous learning and the mindset that it takes to be successful. The entrepreneurship education community has termed this more reflective component the entrepreneurial mindset. The composition and function of a mindset, however, is a much debated topic (Wheadon and Duval-Couetil, 2015).

In the first half of this paper, systems thinking will be used to build a logic model of an entrepreneurial mindset. What arises naturally from this approach is the vital importance of reflection in the development of a robust mindset. Whereas actions are a way to build skills and collect experiences, reflection is the means by which models of the self and world are created and refined (Kolb, 1984). As such, reflection, both formal and informal, is a necessary counterbalance to doing (cpree.uw.edu). In the second half of the paper I will explore some pedagogical tools that incorporate reflection to build mindsets and models of the world. Throughout the paper several statements appear that follow from the logic model. These statements are not facts, but rather are meant to be testable hypotheses that may help move the study of mindset and reflection forward.

Part I: A Systems View of the Entrepreneur
In this section, a logic model will be constructed that will attempt to link together the components that an individual must possess to be an effective innovator or entrepreneur. The diagram is a first prototype, but aims to show the connections between mindset, actions, the model of the world, and reflection. The overall goal is to use these connections to more clearly tease out the nebulous functions of a mindset.

A Systems View of an Entrepreneur
It is a mantra of systems thinking that it is not possible to truly understand anything in isolation (Bateson, 1979; Dorf and Bishop, 1998). One must identify inputs and outputs, and then go on to determine functions. In the system view, it would make little sense to talk about a mindset, divorced from its inputs/outputs and function. From the perspective of an educator, a systems model should also provide insights into how students learn to become innovators or entrepreneurs (Ferguson et al., 2013).

To orient those who are unfamiliar with systems thinking, below is a simplistic view of the world.

![Figure 1](image-url)  
Figure 1: A simple systems block diagram describing how actions impact the world.
In this picture a box represents a system, in this case the world. Inputs to that system are represented as arrows pointing into the system, in this case an action. Arrows pointing out of the system represent outputs, in this case a result of some input action. The arrows imply causality; an action is performed on the world and the effect is some result (Dorf and Bishop, 1998).

Using the graphical language of boxes and arrows, a much more complex systems diagram is shown in Figure 8. This diagram, however, will be created through a series of smaller diagrams that will be combined together.

Automatons and Making Changes in the World
In the 1940’s the group known as the cyberneticists sketched out a diagram to describe a simple automaton that could display goal-directed behavior (Wiener, 1948). An automaton can change the outside world to be in some desired state.

![Diagram of a simple feedback control system](image)

Figure 2: The canonical feedback control system that explains how an automaton takes actions to make the world closer to some desired state.

Such an automaton performs an action and then observes the result. The observed result is then compared to a desired result using a special operator, designated by the circle with the plus sign in the middle (called a junction). In the case of Figure 2, negative feedback is indicated by the arrow with the negative sign entering the junction. The cyberneticists’ claim is that the negative feedback loop is necessary because one action rarely will have the desired effect on the first try. Rather the feedback enables the action to continue to be executed, and adjusted, until the desired state is reached. Such a simple feedback control system is the basis for thermostats, biological homeostasis and many economic phenomena. It is worth noting that actions are skills that are directed out into the world, while observations are a different set of skills that accept information from the world.

What is clearly missing is the origin of the need or desire (Bateson, 1979). So as not to get bogged down in philosophy, we will focus on the goals of an entrepreneur and how these goals may come about. As a first step, an entrepreneur observes something in the world that they think should be changed. In other words, they engage in opportunity recognition. This idea is represented graphically in Figure 3.
What is assumed is that an entrepreneur contains in their mind a model of the world, that describes their personal perception of the real world (Duval-Couetil et al., 2012). They also can imagine a world that they think would be better in some way. It is the difference between the real world and imagined world that forms their value proposition (Boulanger and Tranquillo, 2015; Kim and Tranquillo 2014; Henry et al., 2005). But to gain this value means making the \( \Delta \) (known as an “error” in systems language) between the real and imagined world as small as possible.

**Intentional and Coordinated Actions**

Figures 2 and 3 can be combined together to create a broader picture of how a change agent iterates on their actions.

A key addition is the box labeled “mindset”. The importance of using systems thinking is that it is not necessary to know what a mindset is (what is inside the box) to determine function (how inputs are transformed into outputs). Based upon the position in Figure 4, a mindset is a moderator between the identification of a desired change and actions. Its purpose is to address a critical challenge that is presented by the world. The world itself is composed of many counterbalancing and stabilizing feedback loops (not shown but contained within the box “World”) that make it robust against the actions of a change agent. To create a significant and sustained change therefore requires a change agent to orchestrate coordinated and persistent actions. It is this function that a mindset can provide.

We can also use this diagram to analyze two necessary conditions of a mindset. First, to perform its function, a mindset must be relatively stable on the time scale of the iteration of actions to achieve a desired goal. Otherwise, it cannot serve as a moderator. This logical conclusion has a double edge. On the one hand, it is...
consistency over time that gives a mindset the power to coordinated actions. On the other hand, it means that a mindset takes time to develop. Second, skills and mindsets must work in concert for a change agent to have an impact on the world. A strong mindset, without the skills needed to execute, will not lead to change.

Models of the World
Before defining what a model of the world is (described in Part II), a model for development of that model can be explored. Figure 5 shows a continuous feedback loop that contains the first appearance of reflection. The figure also contains within it the millennia-old philosophical claim that we cannot know the real world as it is. Rather, we construct a model of the world within our self that is a simplified (and perhaps inaccurate) approximation of the real world.

Figure 5: A feedback loop to describe how an individual can refine their model of the world by reflecting on action/observation correlations.

A critical step is that an observation is fed back into a box marked reflection, and it is through reflection that a Model of the World is created and modified. As we take actions, and correlate them with the observe results, we refine our model. The function of reflection is therefore as a mediator between observation and the current model of the world. What makes reflection different from some other boxes is that when it points into a box, it is able to change what is inside that box. Reflection is therefore simply an internal skill that turns observations into changes in the model of the world.

As a skill, reflection can be learned and developed over time (Dewey, 1933). What is critical is that we all subconsciously reflect (Eagleman, 2011). So when entrepreneurs claim that they do not reflect, what they really mean is that they do not consciously reflect. However, like other skills, becoming conscious of reflection and dedicating time and mental energy to practice, will result in more powerful, directed and efficient function (e.g. changing the model of the world).

Figure 5 demonstrates how a model of the world can be modified, but it implies that some initial seed is needed to get the process started. It is not entirely clear where this initial model of the world comes from. Many neuroscientists, however, would tell us that there are intrinsic biases in every species, for example that gravity points down. They would go on to claim that there are more sophisticated biases in humans, for example what a human face looks like, that form an initial, inherited, but incomplete seed, to begin the formation of a model of the world (Pinker, 2003).

It should be noted that a significant portion of our curricula are geared toward building up our students’ Model of the World (Bransford et al., 1999). When we
gather evidence that their world matches our world, even if our world is not correct, we assume that they have successfully learned something.

The Imagined World
The imagined world can be thought of as a copy of the model of the world.

The imagined world is constructed by some components of a mindset, namely creativity, but also likely other components as well. This is a second role for a mindset. As it would be inefficient to create an entirely new imagined world, it is likely that an imagined world is stored only as differences (Δ) from the model of the world. Storing only differences also allows for several imagined worlds to be created and used simultaneously.

Development of a Mindset
Figure 7 is a high level view of how a mindset may develop through self-reflection.

Learning a mindset seems to require observing the results of coordinated actions and extracting learning through reflection (Dewey, 1933; Kolb, 1984). It should be noticed that there is no connection to the outside world in Figure 7. The interpretation is that the “actions” in Figure 7 are simply thoughts. Thinking is only one pathway to mindset development. The full diagram (Figure 8) includes another pathway that loops into and out of the world.
Entrepreneurship Logic Model

The logic model in Figure 8 is a combination of the diagrams above.

Figure 8: Logic Model of the Entrepreneur

With the complete diagram we can note some general points. First, there is a clear divide between the real world and the self. The only links between them are actions and observations and it is through these skills that an individual learns about the world. Second, there is a strong relationship between an individual’s model of the world and their mindset. Both are obtained through watching actions (either their own or some other entity), and then reactions (either internally in terms of emotions and thoughts, or external in the world). There are multiple causal pathways for communication between the mindset and the model of the world. Third, reflection always takes as an input an action/observation correlation, but this singular correlation can be processed in multiple different ways. Lastly, educators often talk of encouraging students to become life long learners (Bransford et al., 1999). In the context of Figure 8, this simply means developing all of the pathways for information flow and using them regularly and synergistically.

Figure 8 proposes that a self maintains a selectively permeable boundary to the outside world. It is of the form of an autopoietic system defined as any “machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network.” (Maturana and Varela, 1980),

Autopoietics was first applied to biological systems, in particular cells, to describe how self-contained networks of functions could catalyze one another and maintain a coherent whole, against perturbations from the outside world. Autopoietic systems achieve this through many interconnected and internal causal loops that move within the system as well as in and out of the world. For example, in the logic model
skills help one interact with the world, which is a primary pathway used in the development of a mindset. But a mindset is what drives the refinement of skills. Likewise knowledge, contained in the model of the world, can lead an entrepreneur to make a change in the world, but then that change is feedback into their own model of the world. These types of non-linear causal loops allow autopoietic systems to become producers of coherent patterns that define the self. The result is that no function (boxes in Figure 8) makes sense without a more holistic view of the entire system (Barab et al., 1999).

There are several consequences of thinking of an individual entrepreneur as an autopoietic system that will be discussed later. Only two will be mentioned here. First, if any one part of the system is weak, or overpowering, relative to the other parts of the system, the entrepreneur will not be able to sustain being a change agent for very long. Second, many autopoietic systems have critical catalyzing functions upon which many other functions depend. These form bottlenecks within the system. Analyzing the logic model, it becomes clear that a mindset is a bottleneck to making change in the world and reflection is a bottleneck to making a change within a self.

Limitations
Of course there are many limitations to Figure 8. First, as a model, it is necessarily a simplification. There are elements that have been left undrawn so as to not overly complicate the diagram. For example, there should be a person’s actual mindset (as drawn), but also a model of their own mindset (what neuroscientists call a Theory of Mind). This would lead to another diagram, similar to Figures 2, 4, and 5, that would be included in the master diagram. Having a model of one’s own mindset and skills maps very well to what we in the entrepreneurship community would call self-efficacy. Second, other people have not been included. The key to adding other people is to assume that they share the same real world. The world is the canvas that people use to communicate with one another. An individual can observe the actions of others, either as individuals or as groups, and include models (again through reflection) of these other individuals into their model of the world. It is by adding other people to the diagram that the logic model could be extended to include empathy, teamwork, joint vision creation and other inherently group activities. Third, skills, knowledge and mindsets, although drawn as discrete boxes, are in reality distributed throughout the system and not as easy to disentangle as drawn in Figure 8.

Part II: The Architecture of Mindsets and Models

The function of a mindset or a model of the world can be inferred from Figure 8. They are, however, shown as black boxes that somehow transform inputs into outputs. In this section, a proposal will be made for the network structure of both models of the world and mindsets. Furthermore, it will be proposed that a network structure leads naturally to both the function and development of mindsets and models of the world.
Models of the World

Wittgenstein described the structure of knowledge as a network of interrelated information (Wittgenstein, 1968). More specifically a mental model of the world is a network of how events and things in the world are interrelated. To know something therefore means to be able to place it within a network. It is the connections between elements of the network that self-make meaning. This idea has had a strong influence on how cognitive neuroscientists think of neural networks storing information (Haykin, 2004), how psychologists think of schemata (Schacter and Tulving, 1994), how linguists think of grammar (Evans and Green, 2006) and how educators think of concepts maps (Novak and Canas, 2008; Turns et al., 2000).

The power of the network idea of internal models is that it explains both how a model is used and how it is acquired. Using knowledge, sometimes called recall, is simply activating or energizing some part of the network. The exact mechanism is not entirely clear, but neuroscientists would point to the coordinated activation of particular neural circuits. At any one time, a person is therefore only activating a particular part of their overall knowledge network.

Knowledge acquisition is simply a change in the network. This is achieved through a combination of adding new information and connections to an existing network (Newman 2010). To get a network started simply requires a seed. As discussed above, most neuroscientists and psychologists agree that some of this seed is inherited from being human, although they disagree on exactly what is innate and what is learned. To sum up, a model of the world is stored in a network structure. Its function, however, arises when parts of that network are activated.

With this picture of a model of the world, the skill of reflection is the mechanism by which the network is changed. What follows is there may be a range of functions that reflection performs. Reflection can reinforce a link that already exists or add a new link. Reflection can also be used to place new information within an existing network, along with the appropriate connections. Lastly, reflection can rewire (e.g. relearning) existing interconnections between information. The impetus for change in each case is observed experiences, but without reflection no changes would be made to the network.

When a change is made to the model of the world, it can be verified (or falsified) based on future interactions with the world (Popper, 2005). We can in fact map Figure 8 to other epistemological ways of knowing, including the scientific method, philosophical (logical) reasoning, and the artistic process. For example, Heidi Neck has mapped the entrepreneurial process to the scientific method (Neck and Greene, 2011). The reason this argument is strong is because all of these ways of knowing relies on the same flows of information between a self and the real world.

There are many takeaways for the educator. First, recall is quite literately a reactivation of the pathways that were constructed through reflection (Bateson,
Second, knowledge networks can have many different structures from being very disconnected or siloed, to very interconnected (Newman, 2010; Neman et al., 2006). There is likely a delicate balance between being underconnected (siloed) and overconnected (the entire network activates). Third, during acquisition, concepts that are activated together will become interconnected with one another (Hebb, 2005). The consequence is that if you learn something in a particular context (e.g. it is structurally embedded in a particular way in the knowledge network), it is most likely to be activated in that context. Furthermore, the timing of observations and path dependencies within the existing network can have a strong influence (often called priming) on how reflection will change the network (Meltzoff et al., 2009).

Fourth, the development of a robust model of the world requires rich observations and time. Fifth, each model of the world will be unique to that individual (Turnes et al., 2000).

Action Networks
Figure 8 contains boxes labeled “coordinated actions” and “observe”, which have been described as skills. Whether mental or physical, these skills have also been proposed to form a network structure (Bateson, 1979). A person will activate particular parts of their network of skills, sometimes in complex and coordinated ways, to achieve an action or observation.

Mindsets
A mindset is proposed to have a similar network structure as a model of the world, but to be focused inward instead of outward. Rather than being composed of things and events, it is a constellation of interconnected attitudes, outlooks, and habits. Figure 9 shows two examples of what the structure of a mindset may look like:

![Mindset Diagram](image)

Figure 9: Two hypothetical mindsets, containing the same elements but connected through different pathways.

A person expresses their mindset internally by activating particular components of their mindset as they need them. The consequence is that a person will not, perhaps cannot, express all of their mindset at any one time. In the literature, this is known as situational expression (Ryan, 2012; Haynie et al., 2010; Brown et al., 1989). For example, when activating grit, an individual will likely need to suppress their
creativity. In this way a mindset is expressed to lend power and coordination to behaviors and actions in an adaptive way.

Like the model of the world, a mindset emerges from a seed. For example, one may be inclined toward being creative. But there may be recognition, through reflection, that creative expression will stall if particular skills are lacking. If a person has adopted a growth mindset (i.e. that they can learn new things through effort) they will seek out ways to learn and practice these new skills. Eventually they will encounter frustration when a particular skill is hard to learn. Failure will prompt the development and activation of resilience and grit. In this way the inclination to be creative will become the seed that can fuel other attributes of a mindset. What emerges over time is a mindset that has several interconnected attitudes, outlooks and habits that all help catalyze one another.

There is in fact a rich literature on different types of networks and how they can grow from an initial seed (Newman et al., 2006; Newman, 2010). For example, the network that emerges may have one strong center (as in a hub and spoke model, left half of Figure 9), or perhaps some other arrangement that is more flat in structure (right half of Figure 9). But each mindset will necessarily be different and will be expressed differently throughout a lifetime.

A network view of mindset may help make some sense of the on-going debate about mindsets. Many researchers argue that there is one keystone attribute that fuels the rest. To Carol Dweck this is a growth orientation (Dweck, 2007) (left half of Figure 9). To the Kern Family Foundation (www.keennetwork.org; Kriewall and Mekemson, 2010; Leslie, 2014) it is curiosity, and to Paul Tough (Tough, 2013) and Malcolm Gladwell it is grit (Gladwell, 2008). Others propose self-efficacy (Bandura, 1977) or intrinsic motivation (Deci and Ryan, 1985; Pink, 2009). What each is proposing is that one attribute is the seed to get things going, as well as the major hub of the mindset. This may in fact be true for particular individuals. But it may also be that researchers have simply constructed research situations that prime subjects to express a particular aspect of their mindset. A network view also means that there is no one “right” mindset, or developmental trajectory, but rather that mindsets are tuned to particular environments.

The primary barrier toward understanding mindsets is that they are notoriously hard to measure (Brown et al., 1989; Duval-Couetil et al., 2010; Haynie et al., 2010; Hisrich et al., 2007). Unlike the model of the world, which is relatively easy for an individual to express in ways that others can see, a mindset is a personal abstraction. Furthermore, the expression of a mindset is situational. The result is that education and educational research programs have focused on skills and knowledge. As a result there is resistance to building educational environments aimed at developing mindsets. It is hoped that a more complete logic model may aid in better assessment of mindset, which will lead to more widespread acceptance of constructing environments aimed at fostering mindset development.
Lastly, as stated above, much of our curricula are focused on models of the world. Recognizing a mindset as a distinct arena of the self, however, means that it may develop at a different rate and through different activities than the domain-dependent development of the model of the world. There are at least two related hypotheses. First, a mindset may be developed through non-formal, non-academic education such as athletics, music, religious life, social interactions, community service or combinations of these activities. Second, elements of a mindset may transfer across domains of expertise. For example, possessing grit in athletics may transfer over to the academic realm.

The Emergent Entrepreneur
When the various networks models are inserted into the logic model (Figure 8), an entrepreneur can be viewed as a complex, adaptive and emergent system (Miller and Page, 2009). Like all emergent systems, the development of an entrepreneur will necessarily arise bottom up rather than being constructed by some top-down plan. Emergence is an idea that is already well represented in entrepreneurship education. For example, prototypes are created and then iterated upon. Hypotheses are made and then real data is gathered to validate or refute claims. What is being proposed here is that an individual becomes an entrepreneur through similar emergent processes.

Another conclusion is that an effective entrepreneur is necessarily strongly coupled to the environment in which they are placed. The dominant entrepreneurial paradigm is that an iterative process enables a product to emerge that is tuned to the world. An individual can likewise become an entrepreneur through their actions, experiences and reflections that are tuned to the world in which they are embedded. This type of self-tuning occurs because an individual is simultaneously using and building their mindset as well as their model of the world (Thompson, 2007).

Insights and Implications for the Educator
Given the individual-focused nature of Figures 8 and 9, there are some serious questions that arise about the role of an educator. The implication is that a mindset cannot be taught, at least not directly. What an educator can do is create an environment that will establish the necessary conditions for mindsets to grow and thrive. A mindset and model of the world will emerge as they are tuned to the environment created by the instructor. The typical classroom intentionally presents a model of the world (usually the instructor’s model) that is simpler than the real world, one without extraneous “noise”. Education in simple settings is enormously beneficial when starting out. But at some point the classroom should become more complex and better mirror the real world. More realistic environments enable students to fine tune their model of the world and strengthen elements of their mindset. Furthermore, it likely does not matter how the real world is experienced, whether it is in open-ended classrooms, internships, co-ops, bootcamps, pop-up classes or hack-a-thons (Boulanger and Tranquillo, 2015; Kim and Tranquillo, 2014).
The elements of a mindset are almost always written about as positive attributes, but an imbalance in some element can become detrimental when it is over expressed. Curiosity and creativity becomes flightiness. Self-efficacy becomes arrogance. Resolve and grit becomes stubbornness and inflexibility. A growth mindset becomes the belief that one can learn and do anything. Of course, there is no right balance and some of the greatest innovators (Isaacson, 2014; Csikszentmihalyi, 2014) were in fact very imbalanced in their mindsets. Their success relied on their mindset being tuned to a select environment and surrounding themselves with other people who could balance their own more extreme mindsets.

The undergraduate and graduate experience does not have a privileged place in the development of mindsets. Long before they were undergraduates, students had profound experiences that will impact them for the rest of their lives. They already learned many skills and began to combine them together intentionally and in coordinated ways. Likewise, after they graduate they will most certainly be relying on the various attributes within their mindset to navigate the world. There is, however, something special about development during the late teens to early twenties (Bransford et al., 1999). They are at a sweet spot where their minds have been seeded with many attributes, but the interconnections have not yet been fully made. As in all complex adaptive systems, new connections often bring about phase transitions (Bak, 2013; Miller and Page, 2009; Newman, 2010). As in other types of phase transition, they occur over a relatively short period of time and result in new behaviors and ways of knowing that were not present beforehand. These are the sorts of individual paradigm shifts (Khun, 2012), which seem to occur very often during the college years.

Many outside of the entrepreneurship and innovation community question the importance of these topics in the education of current and future students. For sure, entrepreneurial experiences are not the only way a rich model of the world and strong mindset can develop. Entrepreneurial environments, however, naturally encourage a student to exercise every pathway in the logic model in Figure 8. An entrepreneur must become very proficient at a diverse range of skills (both action and observation), which may be applied to many domains. Nearly all elements of a mindset will be expressed at different times, sometimes switching very quickly between creativity, grit, and intrinsic motivation. An entrepreneurial environment very quickly exposes flaws in the model of the world. Furthermore, the outputs (products, pitches, value propositions) can be evaluated and form a reasonable picture of the internal processes within an individual. In short, entrepreneurship education builds both a rich model of the world and stimulates the emergence of a balanced mindset.
Part III: Pedagogical Tools

In general, the current educational system has become efficient at encouraging students to practice skills and gain knowledge of the world, perhaps because progress is simpler to measure. As shown in the logic model, however, reflection is the critical skill that fuels the emergence of a strong mindset and model of the world. As humans, all students reflect, whether they know it or not (Könings, 2005). If reflection is viewed as a skill, then practice will enable one to become better at it over time. Furthermore, more intentional, focused, and habitual reflection will result in a mindset and a model of the world that more quickly becomes tuned to the outside world.

There are two primary barriers to adopting reflection: 1) there is already too much content to cover and 2) most faculty have trouble envisioning how to incorporate reflection in their classroom (Borrego et al., 2010). To the first argument, this author would respond that a little intentional reflection seems to go a long way. The remainder of this section will address the second argument, and present a variety of pedagogical techniques for including reflection in educational environments. These techniques have been used in lecture-based courses, problem and project based courses, design boot camps, study abroad, pop-up classes and faculty teaching workshops, within the United States as well as with international audiences. The aim of this section, however, is not to be exhaustive, but rather to encourage and inspire others to find their own way of putting the logic model in sections I and II into practice.

The Reflection Ladder
Most students are familiar with reflection. Unfortunately in many cases the rationale, either explicit or implicit, for producing a reflection is to give the professor insight, rather than for the purposes of student learning. The classic example is the one-time end-of-course reflection. If reflection is a skill that can be developed, then a good first step is to build in repeated reflections throughout an experience. The next step is to give some guidance on how to reflect. Most students when asked to reflect, however, simply summarize events, tell an entertaining story, or even worse, communicate what they think the instructor wants to hear.

Over the past several years, the author has created a framework, called the reflection ladder (Figure 10). Each rung of the ladder contains a higher level of abstraction. A “good” reflection will contain information at each rung. Information at the lower levels is used to build, and integrate across, levels of abstraction as a student “climbs” higher. The ladder analogy has been found to be sticky – “The higher you climb up the ladder the better you can see where you have been, where you are and where you might want to go next”. The author has found this framework to be effective both in guiding students in open-ended reflection time as well as in crafting specific reflection prompts.
Figure 10: Reflection Ladder that serves as a framework for student reflections

**Journals and Portfolios**

Many technical courses emphasize documentation as a practice that is valued by industry, as well as scientific, government and design labs. Documentation in the real world, however, is rarely completed with employee learning in mind. Our dilemma as educators is that we often require students to document their work as a way to prepare them for the workplace. But students who will not be working on a project past the semester have a difficult time seeing the utility in good documentation. Documentation becomes busywork, rather than an important component of their learning.

An alternative is to document progress toward learning goals. There is a large body of literature that in fact addresses this point in the form of portfolios (Kilgore et al., 2014; Penny-Light et al., 2012). These documents are much more than records of what was accomplished. Instead they contain interpretation and reflection on the learning process. The logic model presented could perhaps be used to focus and balance the creation of portfolios as a means of learning.

**Reflection as Story**

There are many who advocate storytelling as a form of reflection and a powerful way to understand the world and self. Gregory Bateson, one of the early pioneers of cybernetics and complex adaptive systems, stated a set of six attributes of any mind (Bateson, 1979). The first attribute on that list was that a mind naturally organizes information in causal structures, otherwise known as a narrative. A story is simply a network of events, agents and objects that interact as they move forward in time. Because story is the way a mind naturally organizes information (Cron, 2012), it is the most efficient way of moving information in and out of a mind (Bateson, 1979).

It is not surprising that many in the entrepreneurship education community have extolled the virtue of good storytelling, but again we encounter a dilemma. The
ability to tell a good story is often viewed in the context of a pitch, targeted toward an audience. An alternative is to view storytelling as a way to make sense of the world and self. A wonderful example of this latter approach is the work of Barbara Karanian where she has asked students to write a narrative about their first interaction with a car (Karanian et al., 2013).

Another example, used by the author in design classes, is to ask students to pick three words from the following list:


For each word they must tell a story that demonstrates how they have embodied that word during the course. Many students shared that these stories caused them to think about themselves very deeply but also had the added benefit that they became ready to answer hard interview questions.

**Student-written Learning Objectives**

It seems to be a given that most courses exists to convey critical knowledge and skills in which the instructor is the expert. It makes sense then that the instructor would write the learning objectives. There are several counters to this position, even if the goal is to teach skills and knowledge, as explained elsewhere (Tranquillo, 2015). A mindset, however, is an individual entity and so it would seem to make sense for an individual to create their own learning objectives. In this spirit, the author often asks students to write two to four of their own learning goals and propose methods of self-assessing their progress toward those goals. All that is required is some instruction on writing learning objectives. A nice side effect of talking about learning objectives is that it becomes more clear how the instructor wrote the course learning objectives.

The author has experimented with this approach in a required Biomedical Signals and Systems class (Tranquillo and Cavanagh, 2007) and Senior Design Capstone sequence. Students were asked to generate two or three individual learning objectives that were mindset-related, meaning they were not to develop a skill or attain some particular knowledge base. They ranged from being more creative to being more confident to better managing frustration. At the end of the course, the final reflection (one of many during the course) was focused on growth toward these individual goals, accompanied by evidence in the form of stories. A similar approach has been used in team-based projects, namely that the team identifies learning goals (often skill or knowledge based) that they will achieve in executing a project.

**Guided Discussion**

Reflection has thus far been framed as an individual activity. For the educator, this is a simplistic position. In fact, there is a great body of psychological literature that
shows the incredible degree to which an individual mindset can be impacted by interaction with other minds. Likewise the educational literature has documented a very significant social component to learning (Brown et al., 1989; Palincsar, 2005; Wenger, 1998). Using the logic model we can begin to understand how student interactions can add to each of their models of the world. First, having a diverse classroom can become an enormous learning benefit, in that it makes the model of the world more realistic and contextually rich. Second, students can share, and challenge, one another’s models of the world. By hearing another explain some aspect of their model of the world, an individual can gain information that will help them validate or refute their own model. Third, as individuals share in a group they reveal aspects of their own mindsets. Listening can often show how others have (or have not) balanced the attributes of their mindset. A deeply reflective person can use these observations to question their own mindset.

Guided discussion, a format that has been used in the humanities for millennia, is a wonderful way for an instructor to facilitate student interactions. The author is the co-director of the six-week summer Institute for Leadership in Technology and Management (www.bucknell.edu/iltm; Tranquillo, 2015; Buffinton et al., 2002) that is non-credit bearing, intense and experiential. Despite the intensity and a need to satisfy an external client, there is much time allocated for group reflection in the form of discussions. Some are formal and scheduled while others are informal and take place during “non-instruction” times, such as bus rides. Having a framework, whether it is the reflection ladder or some other public framework (e.g. McKinsey 7S framework), is critical to guiding these group reflections. Student evaluations report that group reflections are one of the most enlightening components of the program. The author has also introduced discussions into an elective course (Tranquillo, 2014; Tranquillo and Cavanagh, 2007) where students are tasked with making meaning out of a grouping of readings that present counter arguments to one another (Barkley et al., 2014).

Making Conscious One’s Patterns of Behaviors
Another form of reflection is to understand what patterns of behavior (good and bad) one exhibits (Duhigg, 2012). All that is required is to have quick check-ins, of a similar nature to those espoused by self-help gurus, meditation techniques, and several new apps that run on watches and phones. The goal is to make one aware of a habit and turn that recognition into an opportunity for self-reflection. In the author’s senior design capstone, each team must fill in the following for meetings (held each week) with their faculty mentor:

**It has been _____ days since we**

- _____ last reached out to our mentor
- _____ last met with our faculty advisor
- _____ last gained information from someone not on our team
- _____ performed a test or built a portion of our device
- _____ made a critical decision
- _____ made a technical calculation
used information from a previous class
had a team meeting (no mentor or advisor present)
wrote up what we are doing
posted to our design history file

These simple prompts communicate to the faculty mentor where the team is (or is not) investing energy. The process of determining these numbers, however, also prompts a conversation among the team members, which serves as a form of team reflection.

In senior design, and other courses, the author also conducts periodic three to five minute “stand-up” meetings with each individual. For these meetings, a different set of prompts are presented to individuals:

**It has been ______ days since I**

- last took the lead on something
- last did a task I did not want to do
- last did a task that I enjoyed
- contributed something original to the group effort
- took on a challenge
- used something from another class
- started building a habit that I hope to continue later

The instructor gains a snapshot of the investment of that individual, but it is also a simple reflective exercise for the student.

**Signs and Other Reminders**

One way to focus reflection is to post signs around the room. Many companies, such as IDEO, do the same when they post their cultural values in public spaces. These signs reinforce a culture but they also can become the focus of intentional reflections. The author leads the KEEN Winter Interdisciplinary Design Experience (K-WIDE) (www.bucknell.edu/kwide; Kim and Tranquillo, 2014; Boulanger and Tranquillo, 2015) where a primary focus is the development of mindsets. For example, in K-WIDE there are signs with titles such as “Autonomy,Mastery,Purpose” and “Failure to Grow?”. Similar signs have been used in senior capstone design. The instructor can use these signs to prompt reflection.

**Assessment**

A major educational dilemma is how to assess reflection and the growth of a mindset. Some preliminary attempts can be found in the citations, but much more work remains. The logic model at least clarifies why a mindset is hard to assess, namely that it is hidden in the interior of the self, is situationally expressed, and may develop along a different trajectory in different minds embedded in different environments. It also proposes that performing network analyses, similar to how concept maps are used to assess the model of the world, may show promise in assessing mindset. Likewise, when reflection is viewed as a skill, its development
can perhaps be tracked like other skills. There is a body of research that already exists for gaining insights into mindsets, such as standard pre-post surveys, linguistic coding, semantic analysis, network analysis, and others. More specific to entrepreneurship, there are several hybrid measures of innovativeness or entrepreneurial thinking, based largely on concatenating validated psychological measures (Duval-Couetil et al., 2012; Kleine and Yoder, 2011). The Consortium to Promote Reflection in Engineering Education (cpree.uw.edu; Turnes, 2014) has also created a measure of the ‘reflectiveness’ of a person, where they distinguish between types and styles of reflection.

As an example, Figure 11 shows a linguistic analysis of 54 reflections from 18 seniors in a Senior Capstone Design where the reflection ladder was used. The figure was created using the software program Leximancer and goes beyond simple word frequency counts (Smith and Humphreys, 2006). It transforms text into networks that can reveal how concepts are related.

Figure 11: Linguistic network analysis of senior design reflections using Leximancer

These types of analysis can move to another level of depth by making comparisons between maps. For example, the change in an individual’s network maps could be tracked over time. Alternatively maps could be compared across individuals working on a team. Examples of such maps are contained in a previous publication (Boulanger and Tranquillo, 2015).
Conclusions
The engineering entrepreneurship education community has taken on the
development of mindsets as a core tenant of our mission. In this paper, a logic model
was presented that, although incomplete, may help further thinking about goals and
pedagogical tactics. A network structure of a mindset was also proposed to explain
how a mindset develops in concert with an environment and is then situationally
expressed to coordinate actions. Reflection was identified as a vital component in
the building of both a mindset and a model of the world, and a small sampling of
pedagogical techniques were presented that focus on building reflective skills in our
students.

References
Bak, P. How nature works: the science of self-organized criticality. Springer Science &
Business Media (2013).

Bandura, A. Self-efficacy: Toward a unifying theory of behavior change.

Barab, S. et al. Principles of self-organization: Learning as participation in


Borrego, M., et al. Diffusion of engineering education innovations: A survey of
awareness and adoption rates in US engineering departments. Journal of
Engineering Education 99.3 (2010).

Boulanger, B and Tranquillo, J. Blending Entrepreneurship and Design in an


Brown, J., et al. Situated cognition and the culture of learning. Educational
researcher, 18(1), (1989).

Buffinton, K., et al. Project team dynamics and cognitive style. Engineering


