CONNECTIONS

Integrate information from many sources to gain insight.

Activities encourage students to…

- Mentally integrate technical topics, relating one to another
- Contextualize technical solutions, esp. in non-technical domains
- Create diagrams that illustrate relationships among a group of items or concepts (e.g. canvases, ecosystems, mind-maps, etc.)
- Investigate the intersection of seemingly disparate ideas
- Use current affairs in discussions of technical solutions

Goal

Develop *agile mental habits* that interconnect events and information within multiple spheres of contexts and systems.

Example

Our aerospace engineering teaching team uses an instruction technique called "*product connections diagramming*." The idea is similar to creating a mindmap. But rather than mapping ideas or concepts, the diagram contains detailed technical information surrounding an engineered product or service. Imagine a diagram with the product at its center. Groups of three meet at the end of each week to extend the diagram. The extensions are based upon the prior week's course content, some of their own ideas, and specific blocks from the KEEN skillset diagram (e.g. supply chain, testing, regulatory). The FreeMind-based diagram is updated throughout the term.

For example, a group may include a Boeing 737 at its center. After lectures regarding lift, the group will add details to their diagram that include data about the loaded weight, outboard airfoil profile, wingspan; much of which can be obtained through a document regarding airport planning for aircraft (http://www.boeing.com/assets/pdf/commercial/airports/acaps/737.pdf). Additional topics that might not be obvious are added to the diagram as prompted by the instructor, e.g. business models regarding short-hops or long-haul, efficiency, and projected fuel costs. Because it would be difficult to produce an exhaustive complete diagram, it's clearly stated that completeness is not the goal. Rather, the diagram becomes a resource when students pursue an open-ended aircraft design project. The diagram helps them relate to the inevitable trade-offs and interconnected nature of the engineering decisions, business models, environmental concerns, and cultural and demographic considerations.

Assess and manage risk.

Activities encourage students to…

- Think about the potential unintended consequences of their work
- Plan for decisions associated with increasing scale or production, e.g. increases in scale sometimes put tensions on cost, potentially requiring changes in quality, service, etc.
- Evaluate the unanticipated impact due to reuse of designs
- Habitually assess "What if?" with regard to connections to key people, organizations, political environments, regulations, competitors, processes, and design changes. A readiness for change and its consequences is a mental disposition could be supported with skills such as FMEA or safety procedures.

Goal

Increase an *awareness of risks and uncertainty* with an objective approach to handling them.

Example

Senior design projects have become increasingly sophisticated because of KEEN. Previously, students completed a technical design at the behest of the instructor, usually with the instructor serving as the only customer. The economic side of capstone was limited to estimating costs: part, production, and NRE costs. Now, students work on authentic projects for actual industry customers. Still, this alone does not meet all of the educational goals for developing an entrepreneurial mindset. The students had uneven experiences when it came to assessing and managing risk.

In the last offering of senior capstone design, we worked with the industry customers, asking them to help create realistic scenarios for the students that would require risk assessment and change management. In week two, after students had some design direction, groups were asked to make an initial risk assessment and plan.

In the midst of the term, industry customers presented new information that changed design requirements. Others simulated a newly identified problem in the provided equipment the students were using. Still, others actually required a change in the key liaison engineering personnel due to other project demands. Groups were evaluated for their plan and actions.

Application

- What aspects of your project/class develop mental habits around connections?
- What specific student actions or statements showcased connections of this type?
- What specific learning outcomes are targeted at the development of connected thinking?

CURIOSITY

Demonstrate constant curiosity about the changing world around us.

Activities encourage students to…

- Investigate trends
- Generate their own questions
- Challenge assumptions
- Investigate areas of their own choosing
- Assume the role of a "futurist," supporting predictions
- Act on their curiosity

Goal

Exercise *situational curiosity* to increase a student's *dispositional curiosity*, a feature of mindset.

Example

In a biomedical device engineering course, students studying orthopedic devices were asked to investigate demographic trends in the average age within the American population. A follow-up assignment asked students to identify *second-order effects* of their own choosing. These are additional trends that have a cause-and-effect or compounded relationship with the trends regarding age. For example, rising healthcare costs could be considered to be a second-order effect that is coupled to trends in age. At this stage, instructor reviews are encouraging and non-critical. The purpose is to promote some speculation and investigation. Students are then asked to relate all their conclusions to an orthopedic biomedical device design.

Several learning outcomes are contained in the following goal: "Students should be able to choose and investigate societal trends relevant to biomedical engineering decisions, find and analyze data to discover relationships, and speculate on cause and effect." The word choices "choose" and "speculate" intentionally leave directional decisions with the students and promotes situational curiosity. A student's or group's curiosity is further observed when they look beyond the initial assignment. For example, some may investigate global trends in age. Others might predict the increasing age of the population presents an opportunity for devices for lower density. Still, others might identify future surgical challenges or risks. In our case, the opportunity to discuss the assignment for 10 minutes student sparked a conversation in class about the effects of wealth on age.

Explore a contrarian view of accepted solutions.

Activities encourage students to…

- Research alternative solutions, including those that may be currently inferior, but ultimately disruptive
- Consider multiple points of view
- Create a positive atmosphere of constructive criticism
- Offer considered, pertinent feedback to peers and authorities
- Examine data that supports unpopular solutions

Goal

Increase the tendency to be *open-minded* through regular exercises that increase both competence and confidence.

Example

In the first week of class, students within an introductory civil engineering course were given a short assignment regarding the built infrastructure. The purpose of the assignment is to stimulate a contrarian type of curiosity via *critical questions*.

They were given a report titled "*Top Ten Most Controversial Projects*" by Swiss RepRisk. The report offers ten brief synopses of controversial building projects around the world, offering the reason for the controversy. Groups of ten are formed for an initial discussion, and through a D10 dice roll, each member "owns" one project from the report. Students then research news of the project's inception and assume the role of the project's principal engineer.

Each student creates a three-slide, five-minute presentation, which is video recorded and shared with the class through a shared drive. Their first slide explains the project; the second makes a case for its construction; the third suggests what might have been done to improve the project and its public reception. Each class member reviews two video presentations, asking the "principal engineer" three *critical questions* that might have addressed or prevented crisis and controversy. The project develops a curiosity and awareness of the tensions within engineering choices when building in a complex environment. Both the videos and questions contribute to assessment.

Application

- What aspects of your project/class involved this type of curiosity?
- What specific student actions or statements showcased this type of curiosity?
- What specific learning outcomes are targeted at the development of curiosity?

CREATING VALUE

Identify unexpected opportunities to create extraordinary value.

Activities encourage students to…

- Become observers of unmet needs, empathetic ethnographers
- Habitually reframe problems as opportunities
- Ask questions that reveal authentic demand
- Develop archetype users of engineering solutions
- Offer solutions to problems, testing novel ideas with others to obtain formative feedback
- Create value from underutilized resources
- Extend existing solutions to new situations

Goal

Establish a professional identity in which the purpose of engineering is to create value for others from available resources, mathematical and scientific skills, and entrepreneurial agency.

Example

Teaching freshmen engineering courses, I have the opportunity to work closely with departments that teach foundational courses to engineering students, particularly faculty from the Physics Department. Our joint work is beneficial because 75% of Physics II is filled by declared engineering majors; the remaining 25% come from a variety of disciplines, most housed under Liberal Arts & Sciences. Working together, we created a new heat transfer assignment that was distributed in the sixth week of Physics II. This assignment augments traditional homework on the topic and requires three class periods, one-week.

On Monday, the week-long assignment is distributed on a two-sided sheet. Both sides are titled "THERMOS THERMODYNAMICS." One side includes an indicator: "<u>For students of science</u>," and on the reverse, "<u>For students of engineering</u>." Student are instructed to begin on their preferred side, irrespective of major, with the understanding that they would complete all steps on both.

The science-side of the assignment begins with a model drawing of an insulated chamber, annotated with named variables and parameters that govern conduction, convection, and radiation losses. The assignment guides students through the fundamental principles and calculations for heat transfer. A discussion and class activities for of this side of the assignment requires one class period.

The engineering-side is discussed in a second class period. It contains a

Persist through and learn from failure.

Activities encourage students to…

- Treat failures as a moment to learn
- Reflect on challenges and look for areas to improve
- Objectively accept critical feedback

Goal

Develop resiliency through reliance on objectivity and learning upon failure.

Example

I took the KEEN Framework quite literally when adding an element to my Circuits I course. In this first electrical engineering course, failures create learning moments. In fact, students look forward to that last 20-minutes of Friday's Circuits I course that I've dubbed "Epic Fail Friday."

Epic Fail Friday begins with a prepared demonstration that is rolled into class on a cart. The demonstrations are of wide variety: a network of power resistors, a capacitor connected to a fan motor, a piece of consumer electronics. The demonstration is housed under a custom-created acrylic shield. Instrumentation shows key current and voltage measurements on the classroom's projection screen. The demonstrations are versatile; single component changes will either create a demonstration that survives, or fails – usually catastrophically. A microphone captures and amplifies the sound and a charcoal-filter vacuum captures fumes. Other safety precautions include fuses and a fire extinguisher. Demonstrations are designed to fail approximately 3 out of 4 times. But students don't know if a particular demonstration will fail or not.

Before applying power, students are asked to review the circuit diagram containing all details (including wire gauge and length and component ratings) and asked to predict whether the device will fail, how and why. They record their answers on the distributed sheet. Power is applied and students discover if their predictions were correct or incorrect. The entire process is fast.

Full credit (4 pts) is only awarded to correct answers. If students are incorrect, partial credit (2 pts) is awarded for a complete analysis over the weekend.

dimensioned engineering-drawing labeled with material types, thicknesses, and costs, including estimated production costs, guiding students through the design and manufacturing steps. A short video from a Japanese vacuum cup manufacturer, Zojirushi, is viewed. The physical space is important to the process. By viewing the video together as a class, all class members have a shared experience. Because the seating is in small groups around tables, undirected conversations follow in a natural way about a wide variety about technology, working conditions, global manufacturing, etc. In class, student groups propose improvements to the design, citing how their improvements add value and would be tested. Groups continue the work outside of class and prepare a written proposal. Only analytical or data-driven improvements are accepted. However, these need not only be about heat transfer. At the end of the week, a debrief describes the importance of combining skills to create value. It also highlights research data regarding cup reuse, the market size. In the final class session, groups propose an "unexpected opportunity" for insulated vessels. Often, groups will identify needs related to healthcare or food transport. Groups then identify a customer or stakeholder they would contact if pursuing a solution. Because of increased student motivation, the Physics faculty felt the dual assignment was valuable to the heat transfer learning outcomes. The assignment might have been controversial if it were divisive, but because students completed both sides it was not. Comments from a student survey indicate how students organized learning outcomes toward their career goals. We are collecting additional data.	While the segment is entertaining, students are learning important technical content they might not otherwise. The learning is persistent, as verified by an end-of-term quiz about the segment. I plan to augment the demonstrations with stories of actual incidents and products that reaffirm the importance of design.

Application

- What aspects of your project/class promoted creating value?
- What specific student actions or statements showcased value creation?
- What specific learning outcomes are targeted at the development of an understanding of value?