**CURIOSITY**

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| **Demonstrate constant curiosity about the changing world around us.**  **Activities encourage students to…**   * Generate their own questions * Investigate areas outside of the direct problem at hand, yet which can have repercussions on the final design * Investigate non-technical aspects (such as environment) which may be effected by the technical solution * Act on their curiosity   **Goal**  Exercise *situational curiosity* to increase a student’s *dispositional curiosity*, a feature of mindset.  **Example**  Students must investigate the weather trends in the Upper Peninsula of Michigan. Water within piping not buried beneath the frostline will freeze. In addition, design stipulations will need to be considered for any above-ground water tanks.  Students must think about what may be necessary from an engineering standpoint and if they will be able to integrate those aspects within the customers specifications. In other words, they must generate a multitude of questions for the customer. This includes aspects as simple as ground slope, relative distances, lodge size, etc.  Finally students should ultimately be investigating electricity costs, even though this is a project in a Fluid Mechanics course. Running an electric pump can be much cheaper at night when electricity use is low. | **Explore a contrarian view of accepted solutions.**  **Activities encourage students to…**   * Research alternative solutions, including those that may be currently inferior, but ultimately necessary due to constraints * Debate between multiple points of view * Examine data that supports non-standard solutions   **Goal**  Increase the tendency to be view the world around oneself to take notice of multiple solution options.  **Example**  The obvious solution to the problem is to pump water directly from the lake to the cottage and later worry about upgrades for an entire hotel. Unfortunately any upgrade with this solution is not practical. Thus the students should be looking at other methods of water delivery. Water towers are common in cities, yet they are not common in remote areas. A water tower is a contrarian solution for this setting, but based on the advantage they offer, are typically not investigated for a remote hotel. |
| **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? | |

**CONNECTIONS**

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| **Integrate information from many sources to gain insight.**  **Activities encourage students to…**   * Integrate technical topics, relating one to another * Create diagrams that illustrate relationships among a group of items and concepts * Investigate non-technical aspects which will be important for the technical design solution * Integrate information from the customer into the technical solution   **Goal**  Develop *agile mental habits* that interconnect information within multiple spheres of contexts, systems, and disciplines.  **Example**  As related under curiosity, students must investigate weather, electricity costs, ground conditions, sizing requirements based on info from the customer, and a multitude of other non-technical information. All of these aspects must be combined to form a final design solution.  In addition, the students must choose multiple components for their piping and pumping system from a variety of sources (e.g., catalogs and suppliers). They must determine if the components will work together, if they will fit together, etc. Ultimately components must be selected in a very careful order. Until the students have determined valve types, filters, pipe length, number of elbows/valves/tees, they cannot choose a proper sized pump. | **Assess and manage risk.**  **Activities encourage students to…**   * Think about the potential unintended consequences of their work * Plan for decisions associated with increasing scale (e.g., increases in scale puts tensions on cost, potentially requiring changes in design * Include contingency plans due to unforeseen design flaws or “intangibles” * Habitually assess “What if?” with regard to connections to key people, regulations, competitors, processes, and design changes. A readiness for change and its consequences as 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**  Losses associated with piping (water delivery) components are estimates. This is true for both local losses (e.g., valves, elbows, tees, filters) and pipe friction. In fact, the data available for pipe friction is known to have around ±10% accuracy when applied to new piping with no fouling or internal discrepancies. Students must therefore account for a “safety factor” when choosing a pump. Size the pump a bit larger than calculated, and it can be throttled down with a control valve. With that said, a pump too large will be overly costly, so they students must choose within reasonable limits.  A major point of the project is to be able to scale-up the design from a single person cottage to an entire hotel. Choosing the most obvious (i.e., simple) solution of pumping water directly from the lake will later prove to be impractical for a hotel. Using the natural geography with an extended hillside will prove to be the key. An elevated water tank can be filled slowly, but will have the capacity and pressure to supply either cottage or a hotel.  Finally, no question is too minor for the customer. For example, what is the maximum occupancy for the hotel? What auxiliary water systems are in use (e.g., laundry, fountains, café, pool, cleaning, etc.)? The tank must not go empty during high water usage. Thus a water level indicator must be incorporated into the design, and emergency water pumps (of sufficient size) must be at the ready to fill the tank. |
| **Application**   * What aspects of your project 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? | |

**CREATING VALUE**

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| **Identify unexpected opportunities to create extraordinary value.**  **Activities encourage students to…**   * Become observers of unmet needs * Ask questions that reveal authentic demand * Develop engineering solutions that are lower cost yet still practical and meet demand * 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**  Identify a creative method to exceed the stipulations of the customer using available (yet difficult to notice) resources and scientific skills.  **Example**  This skill/mindset to perhaps the most important entrepreneurial aspect of the project. Students will immediately simply notice a lake, a small cottage on the hillside above the lake, and a need to obtain water; the obvious solution is to pump water from the lake to the cottage. The true value to the customer (i.e., hotel owner) is to ultimately obtain water for the entire hotel, not just his cottage. Thus the students must first notice what is most important to the customer – supplying water for his hotel. The size of pump(s) needed for an entire hotel is extremely expensive to both purchase and operate. Therefore, second, the students must take notice of the hidden opportunity that the land presents; the hillside rises steeply above the hotel. This extended hillside has very little practical use. A water tank can be placed on top so that both high capacity and pressure are available without the use of a pump. What’s more, the tank can be refilled each night with a small pump at the lake when very little water or electricity is being used. As such, electricity cost is much lower during these off-peak times and will translate into thousands of dollars in savings for the customer. | **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**  Ultimately, the students will hit roadblocks in their design. This could be choosing a pump too early, before they have realized all of the pressure requirements due to losses. It could be forgetting critical components such as valves for maintenance or flow control. Commonly students begin design calculations at an awkward or difficult step in the water system. The customer is not the only person the students should be asking questions. The course instructor should be questioned to get the design back on track or to overcome a seemingly insurmountable constraint (such as not being able to identify a pump large enough). It is also common that the students will choose their pump based only on pressure needs or only on flowrate needs. Both flowrate and pressure requirements are necessary in pump selection. Pump efficiency is equally important. Many of the design alternates will not only increase complexity but could ultimately unnecessarily increase cost of operation. While these may not be technical failures, they can certainly be value failures. And satisfying the customer is as important as satisfying the technical conditions. |
| **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? | |