

1. Fill in the C0 bubble with a description of the design task. [K→C]

*An example is: C0: Design a human powered vehicle propulsion system.*

2. Generalize or abstract the key elements of the problem to assist with finding inspiration. What are the essential functions? Ask the question, “How does nature \_\_\_\_\_?”

*Examples are: Functions - locomotion, propulsion. Possible question - How does nature move?*

3. Once the problem is reframed, search a database (e.g., www.AskNature.org), observe nature while outside, watch a show about nature, read about nature, etc. to identify a biological system that has analogous properties or characteristics to the problem. Put the name of the inspiring biological system on the line in the Biology Knowledge box. [C→K]

*Example biological system identified: snakes.*

4. Learning from the biological system identified in step 3 and considering what you already know, create a dichotomy (two opposing statements) for the C1 bubbles. One bubble should describe how C0 is traditionally achieved, and the other bubble should describe how C0 is biologically achieved. They should be opposites. Essentially, this is a hypothesis to test. [K→C]

- Explain the C1 (traditional) in the existing solution box in the knowledge space.
- Explain the C1 (biological) in the unexpected property box in the knowledge space.

*Example: C1: Using pedaling motion. (traditional) C1: Without using pedaling motion. (biological)*

*Example explanations: Existing solution - gears with a chain will produce propulsion when turned with a pedal. Unexpected property - snakes do not use rotational movement. They use lateral undulation to move quickly across the ground and push off of bumps to get going.*

5. Dive deeper into the biological information (e.g., books, web search). How does the identified biological system achieve C1 (biological)? Consider physical and non-physical attributes. Write the information in the Biology Knowledge box. [C→K]

- Non-physical attributes - attributes the biological system performs - functions, processes, behaviors, or system characteristics.
- Physical attributes - observable attributes of the biological system - form, shape, geometry, structure, surface, patterns.

*Example biological information for without using pedaling motion: snakes use their muscles and scales to move in four different ways: serpentine motion, concertina motion, sidewinding, and rectilinear motion.*

6. Ask, “How does this biological information connect to what I know?” (intuitive method). If nothing comes to mind, then ask “How does this biological information connect to what is known?” (directed method) and search for information that will allow you to build connections (e.g., analogies, fundamental scientific principles) between the biological knowledge and the traditional knowledge. Write the information in the Traditional Knowledge box. [K→K]

*Example connection building thought process: snakes do not use a pedaling/rotational motion, rather then use a lateral wave motion. Propulsion is also generated by lateral thrust in all segments of the body in contact with the ground. What activities or machines move in a serpentine or sidewinding*

*motion? - Skiing, swimming, roller racer. What activities or machines move in a concertina motion? - leg and chest press*

7. Turn those connections into rough ideas that could solve the design task in C0. Describe the ideas with words in the C2 bubbles. [K→C] Draw arrows from the C1 (biology) bubble being expanded to C2 bubbles.

*Example C2 creation: Serpentine or sidewinding motion ideas - move feet in a side-to-side pattern like skiing, upper body and feet move in a side-to-side motion like roller racer, and move upper body in a wave pattern like swimming. Concertina motion idea - hands and feet press simultaneously.*

8. Expand a single C2 idea or combine C2 ideas to create a design solution(s) in C3. Sketch the solution using engineering components in the C3 bubble. [C→K] Draw arrows from the C2 bubble being expanded to C3 bubble.

*Example C3 creation: One solution for a propulsion system could be a 4 wheeled design that requires the rider to press with alternating leg movements (a wave pattern) to propel the HPV forward like the roller racer.*

9. Indicate the design path using a dashed line with arrow. The design path shows the logical flow of information from the design task in C0 to the sketch in C3.