The Design Pattern: A Blueprint for a New Domain-Specific Assessment
By Louise Yarnall, SRI International

Background on Assessment:

Assessment researchers at SRI International in Menlo Park, CA, designed a prototype scenario-based assessment to measure how well college students learn the big ideas of biology and economics and how to apply those ideas in their everyday lives. The assessment was designed to measure this skill after postsecondary or community college students had completed 2 years of general education courses.

Project Description:

Such understanding of how to apply domain-specific knowledge is considered an important part of building a basis for greater rigor in the educational system and a solid foundation for education of an informed citizenry (Atman et al., 2010). Although a college education has long been viewed as a way to improve students' capacity to think critically and argue rationally, cognitive psychologists and philosophers studying the development of general reasoning have found such skills to be profoundly shaped by the depth of students' core content knowledge of the "big ideas" in different domains (Chi, Glaser, & Farr, 1988; McPeck, 1981). Knowing big ideas differs from one's capacity to recall the random facts, procedures, and concepts of any given domain. Rather, studies of expert thinking suggest that "big ideas" serve as schematic organizers of facts, procedures, and concepts, enhancing the efficiency of higher forms of reasoning, such as argumentation, problem solving, and creativity. The goal was to see how well college students have developed this basic cognitive infrastructure to inform their lives as thinking citizens.

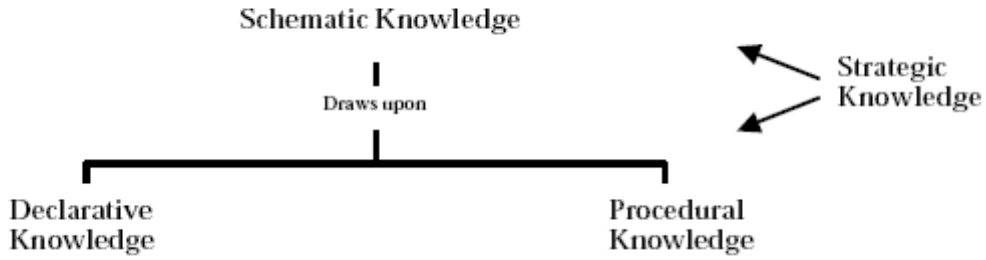
The project team designed and developed assessments using the evidence-centered design approach and is conducting a series of validation studies. The validation studies are: a correlation substudy comparing our instrument with existing assessment instruments, an instructional sensitivity substudy examining change between freshmen and sophomore cohorts, a cognitive analysis substudy involving think-aloud coding, and an alignment substudy featuring an expert panel's review of how our new assessment tasks—and those on existing instruments—align with the different knowledge types we have defined as central to domain-specific understanding.

In spring 2010, SRI administered the resulting prototype assessments in biology and economics to 296 students (148 biology, 148 economics) from a single Northern California community college. A cross-sectional design was employed to compare students at different levels of the general education sequence. The team sampled students from a freshman co-hort that had not taken any college-level biology or economics courses, another co-hort that had taken at least 1 to 2 courses in the domains, and a third co-hort that had taken the full general education sequence in each domain.

The team also grounded its design work in ideas that Shavelson and colleagues (Shavelson, Ruiz-Primo, Li, and Ayala, 2003) have used to distinguish different levels of cognitive complexity and different forms of reasoning.

Strategic knowledge, as depicted by the arrows below, reflects the capacity to know when and how to apply schematic, procedural, and declarative knowledge. It involves domain-specific conditional knowledge and strategies, such as problem-solving, planning, and monitoring progress.
Schematic knowledge describes the principles and models that provide explanations for certain phenomena and which organizes declarative and procedural knowledge.
Procedural knowledge describes the sequential, rule-based activities that lead to expected goals.
Declarative knowledge describes facts, definitions, and statements of key conceptual relations.

Exhibit 1. The structure of knowledge



Source: (Shavelson, Ruiz-Primo, Li, & Ayala, 2003, p. 8)

As shall be seen in this paper later, through the assessment development process, the team has elaborated on these ideas. For example, the team has expanded the different levels of schematic knowledge and specified a wide range of procedures that support reasoning in specific domains.

Present Design Pattern(s):

With the assistance of community college instructors, three from economics and three from biology, the SRI team developed a set of design patterns. These patterns focused on how the instructors expected students would use the knowledge and skills they learned in these general education biology and economics courses in their lives outside of college. They are shown in Table 1.

Table 1. Design patterns

Biology	**Economics**
Using Biological Scientific Principles to Predict Outcomes	Use of Economic Reasoning in Decision Making Situations
Using Biological Scientific Principles to Analyze and Explain Current Health and Environment News	Reasoning about Market Interactions and Equilibriums Using the Supply and Demand Model
Using Scientific Inquiry Methodology	Evaluating Government Policies

For the illustrative purposes, this paper will review the attributes of one of these design patterns and discuss how these attributes integrate cognitive constructs with the domain-specific content. The design pattern for discussion is "Using Biological Scientific Principles to Analyze and Explain Current Health and Environment News." It focuses on the cognitive process of applying domain-specific principles and processes to making decisions in real world situations. The summary of the design pattern captures this idea:

Summary

The design pattern generates assessment tasks that require students to identify relevant biological principles at play in current events related to health and the environment, and then to analyze and critique the reported finding or phenomena using a step-by-step application of the relevant biological principles.

The rationale of the design pattern documents why community college instructors believed this kind of skill is important:

Rationale

Public understanding of current events about scientific findings and phenomena is enhanced when citizens can link those events to core biological principles. Such a skill permits citizens to think critically about scientific discovery that is unfolding during their lives.

Under the Knowledge, Skills and Abilities (KSAs), the team identified 3 types of schematic knowledge and 1 type of strategic knowledge that students need to learn to apply such biological principles to real world situations. The primary distinction between schematic and strategic knowledge is that schematic knowledge concerns how several principles in a domain are defined and related, while schematic knowledge concerns one's ability to use this schematic knowledge fluently to think through a real world problem or situation.

KSAs

Schematic Knowledge	**Strategic Knowledge**
Ability to identify the appropriate biological principle(s) relevant to specific news reports about health and environmental phenomena.	Ability to apply the new information in the news report to situations involving one's personal health, matters of public health, or environmental policy.
Ability to articulate the biological principles and reasoning that are relevant to specific news reports about health and environmental phenomena.	
Ability to place news reports about health and environmental phenomena into a historical context of scientific discovery about essential biological principles.	

Also under the KSAs of the design pattern, the team organized the clusters of essential biology "big ideas"—carbon cycle and evolution—according to the three common types of real world topics in which students would find opportunities to apply these ideas: environmental issues, personal health matters, and public health matters. Below is one example.

KSAs

Public health knowledge: - Knowledge of the importance of monitoring how the public uses drugs to fight pathogens

(e.g., bacteria, viruses) because these are life forms that evolve and may develop resistance to our drugs.
- Knowledge of the importance of promoting widespread public access to practices and procedures such as hand washing, vaccinations, healthy lifestyle, regular physical and dental checkups to monitor body functions and combat/prevent disease, vector control (e.g., mosquitoes), maternal health practices, and genetic testing to maintain quality public health.
- Knowing that studying how living things evolve specific functions for reproduction, development, homeostasis, environmental response, and energy consumption can inform the design of new health treatments that can improve life

In the design pattern, the team also defined the Additional Knowledge, Skills, and Abilities that would not be the focus of the assessment, but would likely influence students' their performance on the assessment. These ranged from general skills of reading and writing and basic arithmetic computation to biological knowledge about processes of osmosis in cell membranes, cellular self-replication, and cellular metabolic pathways.

Potential Observations were described in the design pattern to clarify the aspects of student performance that would provide evidence of the KSAs to be measured by the assessment.

Potential Observations

1. Identification of the correct biological principle(s) used in a news report.
2. Provision of sufficient detail and accurate sequence to explain how the biological principle(s) function in the news report.
3. Specification of a finding in the news report to biological dogma and principles that correctly illustrates how the finding advances prior scientific knowledge. (e.g., so what?)
4. Generation of a set of appropriate new personal or public policy practices that apply the findings in the news report, or, by contrast, being able to explain why the news report does not necessarily lead to any changes in existing personal or public policy practice.
5. Recognition and correction of a common misconception

Work Products were identified in the design pattern that would give students the opportunity to display the relevant knowledge, skills, and abilities. These products included the usual multiple-choice questions and short answer responses, but also included requiring explanations of biological processes around diagrams and arguments for or against a particular policy recommendation.

Finally the team set forth the Characteristic and Variable Features of each assessment task in the design pattern. Through this process, the team specified the stimuli that should be included in any assessment task and the characteristics of the prompts that direct students to engage in applying biological principles to a real world situation. The team also specified how prompts and stimuli would vary depending on whether students were being tested on declarative, procedural, schematic, or strategic knowledge.

Characteristic Task Features	**Variable Features**
Task must include a news report of either a health or	Vary the current popularity or public familiarity of

Task must include a news report of either a health or environmental phenomenon OR a scientific finding relevant to health or the environment.	Vary the current popularity or public familiarity of the topic of the news report.
Task must require students to apply biological principle(s) and either: (1) characterize the relative significance of the news for biological science, or (2) describe the changes in personal or public policy practice that logically flow from the news or (3) do both.	Vary the number of relevant biological principles in schematic item required for application
Declarative tasks focus on just one proposition. The proposition selected should focus on a core definitional understanding that is fundamental to supporting schematic understanding.	Vary the level of technical detail required to explain the relevance of the news
Procedural knowledge should embody the understanding of the domain-specific schema and not be too general purpose.	Vary the genre of information presented (e.g., a mass media report or a popular scientific journal report or an email from a relative/friend or a claim published on a commercial product)
Schematic tasks focus on a relational and combined application of multiple propositions.	Vary the level of detail required in reasoning through a pathway (e.g., metabolic pathways, protein synthesis,...)
All tasks should include language in the prompt to cue relevant schema, i.e., carbon transformation cycle except for strategic tasks, which require the	Vary the level of the concept: descriptive, hypothetical, theoretical.

Assessment Tasks Developed Based on the Design Pattern

The team developed assessment tasks based on its underlying model of how students in college progressed in understanding the biological principles. In all these assessment tasks, students are prompted to apply their knowledge of biology to a real world situation. These tasks differ in the level of cognitive complexity, ranging from relatively basic and definitional (declarative) to relatively complex and judgment-based (strategic).

Type of Knowledge Measured	**Item**
Declarative	The tour guide explained that the polar bear and the grizzly bear occupy distinct “niches” in the ecosystem. Explain what a niche is.
Schematic - Relational	Dr. Geneva stated that it was unlikely that everyone would require the multi-drug resistant TB treatment, which takes several months. One of the theater members protested, saying, “Why not? Why not give us the multi-drug treatment?” In refusing to administer the multi-drug resistant drug treatment to everyone, what specific evolutionary process operating in the TB bacteria was the health officer trying to control? Describe why.
Schematic – Combined Relational Knowledge	People can eat wheat berry seeds and sprouts. Use the principles of energy flow and matter cycling to describe what happens to the amount of energy and mass stored in the wheat berry seeds and sprouts when digested. Explain why.
Strategic	An old wooden shed in the park is falling apart and must be removed to prevent accidents. Two park rangers discuss how

	they could dispose of the shed while minimizing the carbon dioxide emitted into environment. One park ranger says they should just take all of the old wood and bury it. The other ranger says they should burn the wood. Who has the better idea for disposing the shed with minimum impact on carbon emissions? Make a scientific argument to justify your choice.

Summary

The design pattern is sometimes a challenging undertaking for educators to consider. It is neither a test nor an instructional approach. Yet to assessment designers and developers, the design pattern is a tremendous tool for documenting key assessment design decisions in a coherent way. This documentation helps guide the assessment development process at every step, serving as an invaluable tool for designers to track and amend their underlying assessment argument as new data emerge. Ultimately, using the design pattern increases the potential for assessment designers to build assessments with strong content validity because the document enforces a certain discipline of thinking. Using the design pattern requires the assessment design team to review the coherence of their assessment argument at each level of design—from the initial definition of the knowledge and skills to be measured to the tasks that students will perform. This kind of discipline around documentation helps reduce the chance for construct-irrelevant "noise" to creep into the development of the assessment instrument.

In the development of domain-specific assessment tasks, each design pattern served as a editable blueprint for the assessment team. The team recorded each set of design requirements and constraints as it progressed in understanding of the knowledge to be measured and the tasks that could elicit that knowledge.

This particular assessment development project focused on measuring a novel type of learning outcome. The team did not seek to measure "how much" biology and economics students knew. The team sought to measure the ways college students mentally organized their domain-specific knowledge and applied it when confronting real world situations. The design pattern approach helped the team define this knowledge in sufficient complexity to support an organized approach to the development of the assessment instrument. Early results from validation studies indicate that the design pattern process of front-loading the validity argument was worthwhile.

References

Atman, C. J., Sheppard, S. D., Turns, J., Adams, R. S., Fleming, L. N., Stevens, R., Streveler, R. A., Smith, K. A. , Miller, R. L., Leifer, L. J., Yasuhara, K. & Lund D. (2010). *Enabling Engineering Student Success: The Final Report for the Center for the Advancement of Engineering Education*. San Rafael, CA: Morgan & Claypool Publishers.

Chi, M. T. H., Glaser, R., & Farr, M. (Eds.). (1988). *The nature of expertise*. Hillsdale, NJ: Erlbaum.

McPeck, J. E. (1981). *Critical thinking and education*. New York: St. Martin's Press.

Shavelson, R., Ruiz-Primo, M. A., Li, M., & Ayala, C. C. (2003). *Evaluating new approaches to assessing learning*. (No. CSE Report 604). Los Angeles: University of California, Los Angeles, Center for the Study of Evaluation (CSE).

Using Biological Scientific Principles to Analyze and Explain Current Health and Environment News | Design Pattern 2063

[Duplicate | Permit | Delete | View: View (vertical)]

Title [Edit] Using Biological Scientific Principles to Analyze and Explain Current Health and Environment News

Overview [Edit] The design pattern generates assessment tasks that require students to identify relevant biological principles at play in current events related to health and the environment, and then to analyze and critique the reported finding or phenomena using a step-by-step application of the relevant biological principles.

Use [Edit]

U1. Public understanding of current events about scientific findings and phenomena is enhanced when citizens can link those events to core biological principles. Such a skill permits citizens to think critically about scientific discovery that is unfolding during their lives.

Focal knowledge, skills, and abilities [Edit]

Fk1. 1. Ability to identify the appropriate biological principle(s) relevant to specific news reports about health and environmental phenomena. (schematic knowledge)

Fk2. 2. Ability to articulate the tacit biological principles and reasoning that are relevant to specific news reports about health and environmental phenomena. (schematic knowledge)

Fk3. 3. Ability to place news reports about health and environmental phenomena into a historical context of scientific discovery about essential biological principles. In other words, students can demonstrate why certain discoveries are of high interest to the scientific community. (schematic knowledge)

Fk4. 4. Ability to apply the new information in the news report to situations involving one's personal health, matters of public health, or environmental policy. (strategic knowledge)

Fk5. 5. Environmental process knowledge:
- - The understanding that all life on Earth as we know it adapted because of the capacity of plant cells to, through photosynthesis, convert carbon dioxide into more complex forms and release oxygen from water. The related understanding that when organic matter is consumed or destroyed, the carbon released into the atmosphere in the form of CO2 is generated by fungi, bacteria, and animals consuming or destroying the matter. The understanding that the food web reflects nutrient cycles (carbon, nitrogen, phosphorous) that involve transformation of chemical matter and energy from air and water into living plants and animals through cellular processes. The amount of energy transferred dissipates the farther from consuming plants the consumer gets. The understanding that there are two main food webs, aquatic and terrestrial.
- The understanding that the environment is constantly changing and species are adapting to these changes. In natural selection, some members of a population will contain mutations that permit greater survival to these environmental changes. One method of environmental change is by humans, which may occur so rapidly that species do not have time to adapt. The related understanding that evolution of living things is not teleological, but rather, based on replication/reproduction that lead to an expanding diversity of genotypes, and therefore, phenotypes. Selection pressure acts on phenotypes.
- The understanding that when material goes into the soil, these materials are transformed into other forms in large part because of metabolic processes of organisms.
- The understanding that studying how living things evolve specific functions for reproduction, development, homeostasis, environmental response, and energy consumption can inform the design of new technologies that can improve life.
- Familiarity with the hierarchical organization of life. details

Fk6. 6. Personal health knowledge:
- The understanding that body functions are based on maintaining cellular health and therefore the health of the organism; exercise and food intake directly influence the life of cells, including their capacity to convert glucose to energy using oxygen. Cells need a continuous supply of energy to perform a variety of constantly occurring functions. The related understanding that all cells in the body are self-replicating and engaged in a continual cycle of life. In other words, the cells we are born with in our body are not those we die with, but rather the descendants of those original cells.
- The understanding that specialized cellular functions are based on both hereditary and developmental factors. These cellular functions can be disturbed any time in the life of the organism because of problems relating to genetics, aging, poor lifestyle, disease or environmental toxins.
- The understanding that healthy cell functioning is dependent upon the ability to maintain homeostatic internal balance and to respond to changing conditions in the surrounding environment. Disturbances in normal cellular function can lead to health problems or death.
- The importance of using drugs judiciously to fight pathogens (e.g., bacteria, viruses) because these are life forms that evolve and may develop a resistance to our drugs.
- The understanding that studying how living things evolve specific functions for reproduction, development, homeostasis, environmental response, and energy consumption can inform the design of new lifestyle, environmental, and nutrition choices that can improve life. details

Fk7. 7. Public health knowledge:
- The importance of monitoring how the public uses drugs to fight pathogens (e.g., bacteria, viruses) because these are life forms that evolve and may develop resistance to our drugs.
- The importance of promoting widespread public access to practices and procedures such as hand washing, vaccinations, healthy lifestyle, regular physical and dental checkups to monitor body functions and combat/prevent disease, vector control, maternal health practices, and genetic testing to maintain quality public health.
- The understanding that studying how living things evolve specific functions for reproduction, development, homeostasis, environmental response, and energy consumption can inform the design of new health treatments that can improve life. details

Additional knowledge, skills, and abilities [Edit]

Ak1. 1. Familiarity with underlying declarative knowledge of cellular self-replication processes (i.e., a gene and a protein are not the same)

Ak2. 2. Familiarity with underlying declarative knowledge of cellular metabolic pathways for living organisms (photosynthesis) (glycolysis prepares glucose for conversion via anaerobic or aerobic chemical processes; anaerobic is typically less efficient than aerobic) details

Ak3. 3. Familiarity with underlying declarative knowledge that genetic mutation occurs in replicating gene sequences and some of those mutations make a species more adaptable to prevailing environmental conditions.

Ak4. 4. Familiarity with underlying declarative knowledge of osmosis and the basis of exchange through the cell membrane

Ak5. 5. Familiarity with the declarative knowledge that antibiotics do not work alone but rather, must work in partnership with the host immune system

Ak6. 6. Familiarity with underlying declarative knowledge of receptors on cell surfaces to permit delivery of key messages for cellular function and communication. These messages trigger reactions in the cell.

Ak7. 7. Familiarity with the hierarchical organization of life.

Ak8. 8. Basic skills of reading and writing.

Ak9. 9. Ability to interpret and analyze tabular and graphical data.

Ak10. 10. Basic computational and arithmetic skills.

Ak11. 11. Understanding the steps of the scientific method.

Potential observations [Edit]

Po1. 1. Identification of the correct biological principle(s) used in a news report.

Po2. 2. Provision of sufficient detail and accurate sequence to explain how the biological principle(s) function in the news report. details

Po3. 3. Specification of a finding in the news report to biological dogma and principles that correctly illustrates how the finding advances prior scientific knowledge. (e.g., so what?)

Po4. 4. Generation of a set of appropriate new personal or public policy practices that apply the findings in the news report, or, by contrast, being able to explain why the news report does not necessarily lead to any changes in existing personal or public policy practice.

Po5. 5. Recognition and correction of a common misconception

Potential work products [Edit]

Pw1. 1. Multiple choice question (e.g., linking the news finding to appropriate biological principles, such as matching role in carbon transformation cycle--producer, primary consumer, secondary consumer, tertiary consumer, decomposer--to correct species, based on what matter the species consumes)

Pw2. 2. Short answer response

Pw3. 3. Written explanation, with diagrams as needed, to illustrate steps in a biological process details

Pw4. 4. Argument advocating for or against a specific public health or environmental policy recommendation, citing relevant theory from biological principles and evidence from news report

Pw5. 5. A diagram of a nutrient cycle.

Potential rubrics [Edit]

Pr1. 3. Student identifies correct biological principle(s), provides elaborated step-by-step description of underlying biological process, and describes the specific scientific significance (or lack thereof) of the reported finding details

Pr2. 2. Student identifies correct biological principle(s), provides a generally correct sequential description of the underlying biological process, and provides a generally correct characterization of the scientific significance (or lack thereof) of the reported finding. details

Pr3. 1. Student correctly identifies biological principle(s), but may not provide a generally sequential description of the underlying biological process, and does not provide a generally correct characterization of the scientific significance (or lack thereof) of the reported finding. details

Pr4. 0. Student fails to identify the correct biological principle. details

Characteristic features [Edit]

Cf1. Task must include a news report of either a health or environmental phenomenon OR a scientific finding relevant to health or the environment.

Cf2. Task must require students to apply biological principle(s) and either: (1) characterize the relative significance of the news for biological science, or (2) describe the changes in personal or public policy practice that logically flow from the news or (3) do both.

Cf3. Declarative tasks focus on just one proposition. The proposition selected should focus on a core definitional understanding that is fundamental to supporting schematic understanding.

Cf4. Procedural knowledge should embody the understanding of the domain-specific schema and not be too general purpose.

Cf5. Schematic tasks focus on a relational and combined application of multiple propositions.

Cf6. All tasks should include language in the prompt to cue relevant schema, i.e., carbon transformation cycle, except for strategic tasks, which require the student to identify the concepts without overt cues.

Variable features [Edit]

Vf1. Vary the current popularity or public familiarity of the topic of the news report.

Vf2. Vary the number of relevant biological principles in schematic item required for application

Vf3. Vary the level of technical detail required to explain the relevance of the news

Vf4. Vary the genre of information presented (e.g., a mass media report or a popular scientific journal report or an email from a relative/friend or a claim published on a commercial product)

Vf5. Vary the level of detail required in reasoning through a pathway (e.g., metabolic pathways, protein synthesis,...) details

Vf6. Vary the level of the concept: descriptive, hypothetical, theoretical.

Narrative structure	[Edit]	
National educational standards	[Edit]	
State standards	[Edit]	
State benchmarks	[Edit]	
I am a kind of	[Edit]	
These are kinds of me	[Edit]	
These are parts of me	[Edit]	
Templates	[Edit]	Explaining Biological Principles in News Template.
Exemplar tasks	[Edit]	
Online resources	[Edit]	
References	[Edit]	

Tags [Add Tag]

Value	User	Date	
Biology	lyarnall	10/21/08	[delete]
DomainSpecific	lyarnall	10/21/08	[delete]

List of Examples:

Activity Add'l KSAs: Affective Add'l KSAs: Cognitive Add'l KSAs: Executive Add'l KSAs: Language and Symbols Add'l KSAs: Perceptual Add'l KSAs: Skill and Fluency Continuous Zone Design Pattern Educational Standard Evaluation Phase Evaluation Procedure (rubric) Materials and Presentation Measurement Model Narrative Structure Observable Variable State Benchmark State Standards Student Model Student Model Variable Task Exemplar Task Model Variable Task Specification Template Variable Features: Affective Variable Features: Cognitive Variable Features: Executive Variable Features: Language and Symbols Variable Features: Perceptual Variable Features: Skill and Fluency Work Product