PIRPOSAL Model

Conceptual/Pedagogical Framework of Integrative STEM Education

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(**P.I.R.P.O.S.A.L.** Model – Phases of Technological/Engineering Design)

In education there are variations of models depicting the technological and engineering design process used by designers to guide them in developing solutions to any human need. Regardless of form however, all T/E Design Process models reflect iterative approaches, and allowing the designer to start at any phase of the process. The **P.I.R.P.O.S.A.L.** (**P**roblem Identification, **I**deation, **R**esearch, **P**otential Solutions, **O**ptimization, **S**olution Evaluation, **A**lterations, **L**earned Outcomes) model above is different in that it depicts both a theoretical and pedagogical framework for an iterative Design Based Learning (DBL) teaching strategy reflective of designerly ways of thinking and knowing.

PHASES OF TECHNOLOGICAL/ENGINEERING DESIGN

(P) PROBLEM IDENTIFICATION (Need, Define, Formulate)**:** In this phase of design the designer expresses their recognition of the human need requiring a technological solution. When that problem has been identified, it must be operationally defined, and then expressed as a stated problem. At the K-12 level given the amount of teaching time available, the "problem" is often provided within the description of the context and challenge for the selected Problem Scenario (ProbScen). From these descriptions the novice designer can determine the overall purpose and goals for developing the specified technological/ engineering design solution, including identifying the criteria, parameters, and constraints outlined in the context and challenge. Criteria can be defined as principles or standards by which something is judged. Constraints can be defined as variables the designer cannot control and that therefore limits or restricts a design process such as cost, environment, space required, specified materials, and biological capabilities. The Problem Identification section of a student's Interactive Engineering Design

Journal (IEJ) should contain a (1) problem statement, including an introduction and background, (2) statement of the design challenge, and (3) the design specifications (criteria, parameters, and constraints).

(I) IDEATION (Criteria, Brainstorm, Generate)**:** The ideation phase of design is characterized by brainstorming activities, typically a group process, and often runs concurrently with the Research Phase as it generally requires some degree of investigation to learn about variables that may affect, or be affected by the problem. Ideation begins with a review of the information gathered during the Problem Identification phase (criteria, constraints, etc.). While reviewing that information all team members generate a list of (a) what you know about the problem and (b) what you need to know about it. Based on what is individually known and unknown, the team solicits ideas from every member of the group regarding possible solutions to the problem. This free flow of thoughts often spawns other plausible ideas, which at times can include those based on analogies of structures found in nature. Remember that all thoughts are documented in the IEJ, no matter how small or impractical they may appear to be. Assign one member of the team to record all team suggestions and/or recommendations, including all topics discussed, and any sketches or drawings that were suggested. Create a team summary of the brainstorming results (statements, charts, sketches, etc.) and include them in both paragraph and graphic form in the Ideation Section of the IEJ. This information will eventually be incorporated into a final ProbScen report.

(R) RESEARCH (Explore, Investigate, Examine)**:** The research phase of the design process involves searching for information on the various elements of potential solutions. Investigation is a way to discover solutions that have already been tried, which may prove to be useful for your new ProbScen situation. Studying how others have previously addressed the problem helps in developing new ideas for new solutions. As example Problem Scenarios selected from the Design Based Biotechnology Literacy (DBBL) Teaching Guide require incorporation of both technological and biological elements as components of an acceptable design solution. Therefore, it is particularly important to investigate the various technologies, biological processes, and materials that are required by both. Furthermore, based on the ProbScen context and challenge, research is conducted on both of these design elements to better understand the constraints imposed by each. These investigations may take the form of literature searches (books, articles, etc.), discussions with experts on the topic, and web searches for images and examples of systems that have been designed to address similar problems. Many times it is also helpful to look for examples of how nature has solved a similar problem. Throughout the research phase, record all relevant findings in your IEJ, including any diagrams, sketches, or images that might influence your design solution. The dual technological and biological nature of the DBBL ProbScen example requires that each be addressed individually and have specific research portions of the IEJ. Results from these independent ***Research Tasks*** should be included in two distinct IEJ sections: (a) Technological Components section and (b) Biological Components section.

(P) POTENTIAL SOLUTIONS (Analyze, Visualize, Select)**:** Considering all ideas that were generated from team brainstorming and what was discovered while researching the problem, you are now ready to begin deliberate explorations into the variety of possible solutions. During the Potential Solutions phase you want to think about the biology-specific problem(s) you are challenged to solve, and then ask yourself, what basic technologies, materials, designs, and processes might be necessary to support that biology. Such questions often present the designer with decisions that must be made based on conflicting criteria. Ultimately the question is answered when you have enough information to "justify" your decision on a design path that best fits the function of the system required in the solution to the problem. Throughout the Potential Solutions Phase you will need to record in your IEJ all "alternative solutions" generated by the design team to solve the design challenge. In all cases this requires developing a number of detailed sketches of any potential prototype sub-systems, all of which may take you in a number of different directions – different sizes, shapes, environments, systems, organisms, or materials. Generating multiple sketches and drawings allows you to envision your ideas and explore the details they reveal. Visualization can also be accomplished using computer software packages. Include in your IEJ a compilation of all the notes, sketches, and drawings that were used in generating and considering alternative design solutions.

(O) OPTIMIZE (Experiment, Revisit, Construct)**:** When all possible solutions have been explored, the team will then reassess each possible direction for how well it meets the design criteria. The reassessment would include experimentation of potential sub-systems, materials, etc. as a means of gathering evidence for determining the best combination of components leading to an acceptable design solution. Based on these assessments the team determines which sub-systems and/or components provide the "best fit" for addressing the problem. Considerations should range from costs (time, resources, production), to the environmental, sociocultural, and political impacts, to disposal at the end of the product life cycle. Include within the Optimize section of the IEJ a summary paragraph explaining the team's analyses (both quantitative and qualitative), assessment, and reasons for their final selections. Computer software packages are also useful for analyzing both biological and technological elements, as well as modeling interactions among components. Once a final design solution has been selected teams can begin the process of constructing a prototype of their system. The prototype solution is typically a scaled, working model of a design that attempts to have complete function, behavior, and structure of the intended technical system. This prototype is used to test design concepts by conducting actual trials, making specific observations, and performing any necessary adjustments to the scaled model.

(S) SOLUTION EVALUATION (Test, Analyze, Interpret)**:** The prototype is intended to demonstrate a proof of concept. The Solution Evaluation phase should therefore be done in a way that will address each of the criteria described in the design challenge. The more important considerations to address during the Solution Evaluation phase are as follows:

a) List all attributes that address the design criteria and therefore are important to test
b) Develop a set of sub-experiments that will address each of the attributes listed above (depending on circumstances, you may also consider developing these experiments to test the system under both controlled conditions and in the working environment)
c) Gather, record, and analyze data collected, and compare these results to the original design specifications. Both quantitative and qualitative results from tests conducted to evaluate all criteria should be recorded in the IEJ. Include as well observation notes, sketches, and photos in this section of the IEJ
d) Based on the analysis of data, prepare a summary of the findings, including where the design exceeded and/or failed specifications
e) Describe the implications, both individual and team perspectives, from the evaluation of their chosen design (include system failures as well as areas of major concern to be addressed in any redesign or refinement)

(A) ALTERATIONS (Identify, Redesign, Retest)**:** It is rare that initial designs meet all design criteria. Invariably there are problems with all design attempts, which leads to the need for redesigning or fine tuning of the original system. The evaluation will provide the design team with a list of issues still to be addressed, which leads the team back to the initial design phase and the need to "define the problem" once again. Technological/Engineering design is an iterative process, where successive iterations take you one step closer to an acceptable design solution.

(L) LEARNED OUTCOMES (Process, Iterations, Justify)**:** When the Alterations phase results in a refined solution that most successfully addresses the design criteria, the final phase is communicating the Learned Outcomes. The Learned Outcomes are communicated through a combination of written, visual, and verbal presentation and discussion of the final design solution, with particular attention paid to the distinct biological and technological details addressed throughout the entire design process. The Learned Outcomes are inclusive of the content and practice (tacit) knowledge utilized in making informed decisions based on relevant STEM concepts and theory. At the classroom level this will take the form of a detailed IEJ that reflects all phases of design as described above, and concludes with a final ProbScen Report, which includes all sketches and/or detailed design drawings, the final prototype (system artifact), and a PowerPoint presentation.