

Template for how the RED might be used

Table 2: Rubric for Experimental Design (RED)

Areas of Difficulty	Propositional Statements/Completely Correct Ideas	Typical Evidence of Difficulties	Example of difficulties from the ‘Shrimp Assessment’
(1) Variable Property of an Experimental Subject	<p>Experimental subject or units: The individuals to which the specific variable treatment or experimental condition is applied. An experimental subject has a variable property. A variable is a certain property of an experimental subject that can be measured and that has more than one condition.</p>	<p>a. An experimental subject was considered to be a variable. b. Groups of experimental subject were considered based on a property <i>that diverges</i> from the subjects that were the target for the stated investigation or claim to be tested. c. Variable property of experimental subject considered is not consistent throughout a proposed experiment.</p>	<p>“The tiger shrimps act as the control group” “One advantage by using the same shrimps is that you only have to collect data from the one type of shrimp.”</p>
(2) Manipulation of Variables	<p>Testable hypothesis: A hypothesis is a testable statement that carries a predicted association between a treatment and outcome variable. (Ruxton and Colegrave, 2006).</p>	<p>a. Only the treatment and/or outcome variable is present in the hypothesis statement. b. Hypothesis does not clearly indicate the expected outcome to be measured from a proposed experiment.</p>	<p>“...Low salinity with no nutrient, High salinity with no nutrients...”</p>
	<p>Treatment group: A treatment group of experimental subjects or units is exposed to experimental conditions that vary in a specific way (Holmes, Moody and Dine, 2011).</p>	<p>c. Haphazard assignment of treatments to experimental units in a manner inappropriate for the goal of an experiment. d. Treatment conditions proposed are unsuitable physiologically for the experimental subject or inappropriate according to the goal of an investigation.</p>	<p>“Regular water, low dosage saline water, high dosage saline water.”</p>
	<p>Combinatorial reasoning: In experimental scenarios when two or more treatment (independent) variables are present simultaneously, all combined manipulations of both together are examined to observe combinatorial effects on an outcome.</p>	<p>e. Independent variables are haphazardly applied, in scenarios when the combined effects of two independent variables are to be tested simultaneously. f. Combining treatments in scenarios where the effect of two different treatments are to be determined individually</p>	<p>“One tank would be the control with no salt or nutrients”</p>
	<p>Controlling outside variables: The control and treatment groups are required to be matched as closely as possible to equally reduce the effect of lurking variables on both groups (Holmes, Moody and Dine,</p>	<p>g. Variables unrelated to the research question (often showing a prior knowledge bias) are mismatched across treatment and control groups.</p>	<p>“...Low salinity with no nutrient, High salinity with no nutrients...”</p>

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	<p>2011).</p> <p>Control group: A control group of experimental subjects or units, for comparison purposes, measures natural behavior under a normal condition instead of exposing them to experimental treatment conditions. Parameters other than the treatment variables are identical for both the treatment and control conditions. (Gill and Walsh, 2010; Holmes, Moody and Dine, 2011).</p>	<p>h. The control group does not provide natural behavior conditions because absence of the variable being manipulated in the treatment group, results in conditions unsuitable for the experimental subject.</p> <p>i. Control group treatment conditions are inappropriate for the stated hypothesis or experiment goal.</p> <p>j. Experimental subjects carrying obvious differences are assigned to treatment vs. control group.</p>	<p>“There would then be tanks with no salt but with nutrient A in one, B in another, and C in the last.”</p> <p>“control samples, where shrimp were not given the nutrients”</p>
(3) Measurement of Outcome	<p>Treatment and outcome variables should match up with proposed measurements or outcome can be categorical and/or quantitative variables treatments</p> <p>A categorical variable sorts values into distinct categories.</p> <p>A quantitative or continuous variable answers a "how many?" type question and usually would yield quantitative responses.</p> <p>Outcome group: The experimental subject carries a specific outcome (dependent variable) that can be observed/measured in response to the experimental conditions applied as part of the treatment (Holmes, Moody and Dine, 2011).</p>	<p>a. No coherent relationship between a treatment and outcome variable is mentioned.</p> <p>b. The treatment and outcome variables are reversed.</p> <p>c. Outcome variables proposed are irrelevant for the proposed experimental context provided or with the hypothesis.</p> <p>d. Stated outcome not measurable.</p> <p>e. No measure was proposed for the outcome variable.</p> <p>f. An outcome variable was not listed for an investigation.</p> <p>g. There is a mismatch between what the investigation claims to test and the outcome</p>	<p>“The biologist could use a bar graph showing the growth on the y axis and the method used on the x axis to clearly show the differences in results.”</p>

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(4) Accounting for Variability	Experimental design needs to account for the variability occurring in the natural biological world. Reducing variability is essential to reduce effect of non-relevant factors in order to carefully observe effects of relevant ones (Box <i>et al.</i> 2005; Cox and Reid 2000).	variable.	“...a researcher can confidently expect to find a repetitive response to a given exposure in a group of genetically identical tiger shrimps.”
	Selection of a random (representative) sample: A representative sample is one where all experimental subjects from a target demographic have an equal chance of being selected in the control or treatment group. An appropriate representative sample size is one that averages out any variations not controlled for in the experimental design. (The College Board, 2006; Holmes, Moody and Dine, 2011).	<p>a. Claims that a sample of experimental subjects will eliminate natural variability with those subjects.</p> <p>b. Criteria for <i>selecting</i> experimental subjects for treatment vs. control group are biased and not uniform.</p> <p>c. Criteria for selecting experimental subjects for investigation are different in a way that is not representative of the target population.</p>	
	<p>Randomized design of an experiment: Randomizing the order in which experimental subjects or units experience treatment conditions as a way to reduce the chance of bias in the experiment (Ramsey and Schafer, 2012).</p> <p>Randomization can be complete or restricted. One can restrict randomization by using block design which accounts for known variability in the experiment that can’t be controlled.</p>	<p>d. Decisions to <i>assign</i> experimental subjects to treatment vs. control group are not random but biased for each group.</p> <p>e. Random assignment of treatments is not considered.</p> <p>f. Random assignment of treatments is incomplete as they show random assignment of the experimental subjects but instead, what is needed is random assignment of treatments.</p>	“With all the shrimp in one tank, one by one randomly assign a shrimp to a tank [...] by doing this, the biologist is aware of which tanks contain which ingredients but the shrimp are completely randomized.”
	Replication of treatments to experimental units or subjects: Replication is performed to assess natural variability, by repeating the same manipulations to several experimental subjects (or units carrying multiple subjects), as appropriate under the same treatment conditions (Quinn and Keough, 2002).	<p>g. Replication means repeating the entire experiment <i>at some other time</i> with another group of experimental subjects.</p> <p>h. No evidence of replication or suggested need to replicate as a method to access variability or to increase validity/power of an investigation.</p>	“...a researcher can confidently expect to find a repetitive response to a given exposure in a group of genetically identical tiger shrimps.”

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(5) Scope of Inference of Findings	<p>Scope of inference: Recognizing the limit of inferences that can be made from a small characteristic sample of experimental subjects or units, to a wider target population and knowing to what extent findings at the experimental subject level can be generalized.</p>	<p>a. The inference from a sample is to a different target population. Usually students under- or overestimate their findings beyond the scope of the target population.</p>	<p>“Data gathered will only be applicable to the shrimp tested, not shrimp or sea organisms in general.”</p>
	<p>Cause and effect conclusions: A cause-and-effect relationship can be established as separate from a mere association between variables only when the effect of lurking variables are reduced by random assignment of treatments and matching treatment and control group conditions as closely as possible. Appropriate control groups also in comparison to the treatment group also need to be considered (NIST/SEMATECH, 2003; Wuensch, 2001).</p>	<p>b. No steps are carried out to randomly select experimental subjects' representative of the target population about which claims are made.</p>	<p>“Concentrate certain nutrients to specific tanks and note the difference once the 3 weeks have passed by”</p>
		<p>c. A causal relationship is claimed even though the data shows only association between variables. Correlation does not establish causation. (NIST/SEMATECH, 2003)</p>	<p>“...this fails to demonstrate how a given ingredient may affect another type of shrimp. Ultimately it limits the depth of the study.”</p>