11-1-2016

Guidelines to Avoid Typical Difficulties According to the Rubric for Experimental Design (RED)

Annwesa Dasgupta
Purdue University

Nancy Pelaez
Purdue University, npelaez@purdue.edu

Recommended Citation

Dasgupta AP, Pelaez N (2017). Student Guidelines to Avoid Typical Difficulties According to the Rubric for Experimental Design (RED), adapted from Dasgupta AP, Anderson TR, Pelaez N (2014). Development and Validation of a Rubric for Diagnosing Students' Experimental Design Knowledge and Difficulties. CBE Life Science Education 13, 265-284

Guidelines to Avoid Typical Difficulties According to the Rubric for Experimental Design (RED)

Areas of Difficulty	Correct Ideas	Guidelines to Avoid Typical Difficulties
(1) Variable Property of an Experimental Subject	**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.	**a.** Know that your experimental subject is not a variable. **b.** What groups of experimental subjects would have a variable property *in line* with the target for the stated investigation or claim to be tested? **c.** Be consistent in your use of appropriate experimental subjects with relevant variable properties throughout your proposed experiments.
(2) Manipulation of Variables	**Testable hypothesis:** A hypothesis is a testable statement that carries a predicted association between a treatment and outcome variable. (Ruxton and Colegrave, 2006).	**a.** Did you mention BOTH the treatment and/or outcome variables in the research question or hypothesis statement? **b.** Do your hypotheses and predictions clearly indicate the expected outcome to be measured from a proposed experiment?
	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).	**c.** Did you assignment treatments to experimental units in a manner appropriate for the goal of your experiment? **d.** Did you use only treatment conditions that are suitable physiologically for the experimental subject according to the goal of your investigation?
	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.	**e.** Did you systematically consider all combinations of treatments in scenarios where the effect of two or more different treatments are to be determined?
	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, 2011).	**g.** Did you match appropriate variables to the research question across treatment and control groups (avoiding a prior knowledge bias)?
	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).	**h.** Did the control group provide an opportunity to observe natural behavior conditions in the absence of the variable being manipulated in the treatment group, because conditions for both groups were suitable for the subject? **i.** Were the control group treatment conditions appropriate for the stated hypothesis or experiment goal? **j.** Did you avoid any obvious differences when assigning experimental subjects to the treatment vs. control group?
(3) Measurement of Outcome	Treatment and outcome variables should match up with proposed measurements or outcome can be categorical and/or quantitative variables treatments A categorical variable sorts values into distinct categories. A quantitative or continuous variable answers a "how many?" type question and usually would yield quantitative responses.	**a.** Did you mention and consider the relationship between a treatment and outcome variable? **b.** Do not reverse the treatment and outcome variables. c. Do not treat an outcome variable that is quantitative as a categorical variable.

Adapted from Dasgupta, Anderson, & Pelaez, CBE Life Sciences Education 13: 265-284, 2014 (doi:10.1187/cbe.13-09-0192).

Guidelines to Avoid Typical Difficulties According to the Rubric for Experimental Design (RED)

Areas of Difficulty	Correct Ideas	Guidelines to Avoid Typical Difficulties
	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).	**c.** Did you propose outcome variables that are relevant for the proposed experimental context provided or with the hypothesis? **d.** Is your stated outcome not measurable? **g.** Is there a good match between what the investigation claims to test and the outcome variable?
(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 *et al.* 2005; Cox and Reid 2000).	**a.** Given that a sample of experimental subjects cannot eliminate natural variability with those subjects, did you propose to collect data on variability?
	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).	**b.** Did you propose uniform criteria for *selecting* experimental subjects for treatment vs. control groups?. **c.** Did you propose criteria for selecting experimental subjects for investigation in a way that is representative of the target population?
	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). 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.	**d.** Did you randomly *assign* experimental subjects to treatment vs. control group without any bias for members of each group. **e.** Did you randomly assignment treatments to the groups and not just random assignment of the experimental subjects, since what is needed is random assignment of treatments?
	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).	**g.** Did you do replications by repeating the entire experiment *at some other time* with another group of experimental subjects? **h.** Do you show evidence of replication or suggest a need to replicate as a method to access variability or to increase validity/power of an investigation?
(5) Scope of Inference of Findings	**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.	**a.** Did you propose an inference from a sample that is appropriate to the same target population? Did you refrain from under- or overestimating your findings beyond the scope of the target population? **b.** Did you carry out steps to randomly select experimental subjects' representative of the target population about which claims are made?

Adapted from Dasgupta, Anderson, & Pelaez, CBE Life Sciences Education 13: 265-284, 2014 (doi:10.1187/cbe.13-09-0192).

Guidelines to Avoid Typical Difficulties According to the Rubric for Experimental Design (RED)

Areas of Difficulty	Correct Ideas	Guidelines to Avoid Typical Difficulties
	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).	**c.** Did you appropriately decide if a causal relationship is warranted or if the data shows only association between variables? Correlation does not establish causation.

Adapted from Dasgupta, Anderson, & Pelaez, CBE Life Sciences Education 13: 265-284, 2014 (doi:10.1187/cbe.13-09-0192).