Writing Sample 2 - Research Experiments

March 2020

1 Introduction

The first recorded research experiment in human history was recorded in 1021. An Arab physicist, Ibn al-Haytham, followed a series of steps to confirm a long-standing theory that light was generated from objects rather than from the human eye. Ibn al-Haytham's use of what he saw, his notes, and his process would go on to inspire what would come to be known as the Scientific Method of research.[4] In the modern-day, scientists utilize the scientific method to design an experiment to discover "empirical evidence" for a proposed hypothesis. [2]. This evidence is gathered and then analyzed by a researcher to arrive at a conclusion that relates to the hypothesis. As an introduction to research experimentation, it is valuable to provide an understanding of the scientific method that every researcher will use in some form.

2 The Scientific Method

Khan Academy, a website dedicated to educating on a large number of topics, provides the following model for understanding the scientific method. Pieces of the article have been merged for simplicity. [1]

2.1 Observe and Ask a Question

The researcher's first step in conducting the scientific method is to **observe** something that they do not have an immediate answer for. In Computer Science, this can take the form of unexplained behaviors in compilers, for Biologists this might be the sleep cycle of certain animals. From there, the researcher must then form and **ask a question** that relates to the behavior just observed. George Mason University[7] recommends that a research question follows five criteria:

1. **Clear:** The question has all the details a reader needs to understand the problem.
2. **Focused:** The question is narrow in scope and only deals on the exact information the researcher is looking for

3. **Concise:** The question should be as short as possible, but no shorter. [5]
4. **Complex:** The question extends further than a "yes" or a "no"[7]
5. **Arguable:** The answer is open to debate; it is not a fixed outcome.

Our earlier research question, "Why is the g++ compiler running slow on the AND command?" fulfills our criteria. With a proper research question developed, we go forth into the hypothesis and prediction stage.

2.2 Form a Hypothesis and Make a Prediction

A proper hypothesis must fulfill two criteria: it must offer a **potential solution** to our question, and it must be **testable**. [1] An example hypothesis to our ongoing example research question could be "The SUB, COMB, and MIN operations that ADD is built on are running at lower than full capacity on the g++ compiler, causing our ADD operation to run slow". This hypothesis offers a **potential solution** to our question: if the pieces of what makes up the ADD command are running slow, the ADD command is sure to be slow. The hypothesis is also **testable**, as we can determine whether or not the SUB, COMB, and MIN are running as expected or not. How the researcher decides to orchestrate that test is called **Experimental Design**.

2.3 Design the Experiment

When designing an experiment, there are several important principles to keep in mind. [6] Where applicable, experiments should be **randomized** to help eliminate bias from the results. In the case of our research question, this category is not as applicable, but for the sake of something that is survey based, randomization plays a huge role in avoiding sampling bias. Another important idea is that of **replication**, where the researcher is able to perform the same experiment multiple times and achieve similar results. This also helps to eliminate "environmental noise" or anything that can skew a single result. In our example, we may to run the g++ test 10,000 times and make conclusion based on that whole body of data as opposed to a single run. As final note on experimental principles, **blocking** is the practice of fixing as many "control" variables as possible. These variables that stay the same among all tests conducting. In our example, it is advisable to focus on running all of our tests on the same computer, with the same compiler options, with the same processes running such that these values do not impact us recording command run times.

2.4 Gather Data

Effective experiment design relies on the preceding principles, coupled with a few additional areas of importance.[6] The first is that independent variable(s), or input, should be modified to observe changes in dependent variable(s). We can change our independent variable (separate or ADD function use) and then

see the change in our dependent variable (elapsed time) in order to conduct a meaningful experiment.

In order to provide good research, our experiment needs to provide results that are "valid, easily interpreted, and definitive"[6]. The g++ experiment that is intended to gather elapsed time will be useless to us if the results are set up to provide only processor performances. Additionally, the data obtained must be gathered in an effective and systematic such that it can be properly analyzed.

2.5 Test and Analyze

With the research question determined, the hypothesis stated, and the experiment designed, the researcher tests their hypothesis by running the experiment. Upon the completion of the experiment, the researcher conducts data analysis from among several tests to determine if the data is statistically significant or not. [3] In our g++ example, the researcher would be able to tell if the SUM, COMB, and MIN operations are what is slowing down the ADD operation based on a statistical analysis of the results of the two groups discussed previously.

3 Conclusion

The process outlined by the scientific method is a tried and true route to conduct a research experiment. Regardless if the hypothesis is true or false, the researcher can write a paper on their attempt, and the researcher or others can try something new, repeating the whole process. All fields of research, regardless of domain, require the formulation of a research question, the development of a hypothesis, and the creation and testing of an experiment. Research experiments are what fuel the development of scientific discovery and action.

References

[1] Khan Academy. The Scientific Method (Article).

[2] Alina Bradford. What Is Science? *LiveScience*, Aug 2017.

[3] J. Bruin. What Statisical Analysis Should I Use? StatisicalL Analyses Using SPSS, February 2011.

[4] David C. Lindberg. *Theories of Vision from Al-Kindi to Kepler*. Univ. of Chicago Press, 1996.

[5] QuoteResearch. Everything Should Be Made as Simple as Possible, But Not Simpler, Oct 2018.

[6] Statistics How To. Experimental Design, 2020.

[7] George Mason University. How to Write a Research Question, Aug 2018.