THE ART OF SOFTWARE INVESTIGATION

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Based on

THE ART OF SCIENTIFIC INVESTIGATION

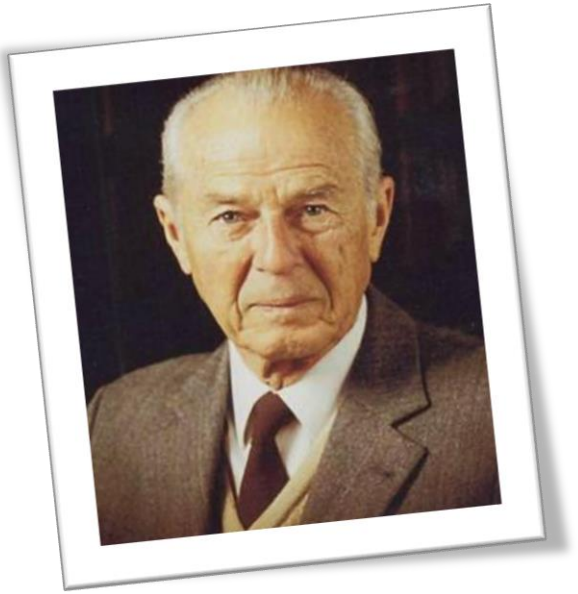
By W. I. B. Beveridge

1950

SOFTWARE INVESTIGATION

THE ART OF SCIENTIFIC INVESTIGATION

By William Ian Beardmore Beveridge



An entirely fresh approach
to the intellectual adventure
of scientific research

1950

SOFTWARE INVESTIGATION

A SEARCH FOR NEW KNOWLEDGE

CONTENTS

- PREPARATION
- SELECTION
- SEQUENCE
- EXPERIMENTATION
- CHANCE
- HYPOTHESIS
- IMAGINATION
- INTUITION
- REASON
- OBSERVATION
- INVESTIGATORS
- DISCUSSION

Scientific research
is not itself a science;
it is still an art or craft.

- W. H. George

PREPARATION

SELF-DIRECTED LEARNING

- Knowledge
  - Build a foundation
  - Keep current
  - Maintain independence
  - Cultivate diversity
  - Understand history
- Fluency
  - Communicate & think with clarity
- Confer
  - Participate in the greater community

The research worker remains a student all his life. Preparation for his work is never finished for he has to keep abreast with the growth of knowledge.

- W. I. B. Beveridge

SELECTION

CHOOSE YOUR OWN WORK

- Interest encourages success
  - If work is chosen for you, seek out an aspect that provokes interest
- Select work that
  - has a chance of success
  - Is within your technical abilities

> Start with a problem in which there is a good chance of his accomplishing something, and which is not beyond [your] technical capabilities.
>
> - W. I. B. Beveridge

SEQUENCE

ITERATE

1. Review
2. Observe
3. Analyze
4. Guess
5. Experiment

The most effective experimenters are usually those who give much thought to the problem beforehand and resolve it into crucial questions and then give much thought to designing experiments to answer the questions.

- W. I. B. Beveridge

EXPERIMENTATION

TWO TYPES OF INVESTIGATION

- Observational
  - Collection of data from naturally occurring phenomena
- Experimental
  - Collection of data from an event made to occur under controlled conditions

A basic concept … is that there is an infinitely large, hypothetical population of which the experimental group or data are a random sample.

- W. I. B. Beveridge

All investigation is sampling

EXPERIMENTATION

EXECUTION

- Start modestly
  - Pilot
  - Sighting
  - Screening
- Take notes
  - Document as you go
- Iterate
  - Design later experiments based on results of earlier ones
- Stop
- Be competent
  - Techniques
  - Tools
  - Subject

> It happens surprisingly often that one needs to refer back to some detail whose significance one did not realize when the experiment was carried out.
>
> - W. I. B. Beveridge

EXPERIMENTATION

STATISTICS

- Caution
  - People give numbers more credence than they deserve
  - Averages are often misleading
  - Graphs are often misleading

The use of statistics does not lessen the necessity for using common sense in interpreting results, a point which is sometimes forgotten.

- W. I. B. Beveridge

EXPERIMENTATION

MISLEADING EXPERIMENTS

- Mistakes
  - "Honest" mistakes
  - Incompetent experimenters
- Contamination
  - Accidental or unknown influences
- Difficult to prove a negative

Experimentation, like other measures employed in research, is not infallible.

Inability to demonstrate a supposition experimentally does not prove that it is incorrect.

- W. I. B. Beveridge

EXPERIMENTATION

EUREKA

- Reproduce it
- Look at it from multiple perspectives
- Connect it with other knowledge
- Seek new avenues of investigation

> The real and lasting pleasure in a discovery comes not so much from the accomplishment itself as from the possibility of using it as a stepping stone for fresh advances.
>
> - W. I. B. Beveridge

CHANCE

THE ROLE OF CHANCE

- Chance plays an important part in discovery
  - Chance alone does not discover
  - Chance provides opportunity to the keen observer
  - Significance comes from an observer relating observations to other knowledge

> In the field of observation, chance favors only the prepared mind.
>
> - Pasteur

CHANCE

COURTING CHANCE

- Prepare your mind to recognize useful information
- Entertain ideas that contradict beliefs
- Be unconventional
- Maximize the risk of having a fortunate accident
- Postpone demand for evidence
- Perform many experiments

Chance favors only those
who know how to court her.

- Charles Nicolle

CHANCE

RECOGNIZE & EXPLOIT

- Be alert for the unexpected
- Don't be blinded by hypothesis
  - Follow up on interesting side-issues

Acute powers of observation are often required to notice the clue, and especially the ability to remain alert and sensitive for the unexpected while watching for the
expected.

- W. I. B. Beveridge

HYPOTHESIS

A TOOL FOR DISCOVERY

- Suggests new
  - Experiments
  - Observations
- Helps provide significance to what we observe
- Most will be wrong
  - Be prepared to abandon them

In science the primary duty of ideas is to be useful and interesting even more than to be 'true'.

\- Wilfred Trotter

HYPOTHESIS

PRECAUTIONS

- Once an opinion is formed, it becomes difficult to think of alternatives
- Don't get too attached to your brainchild
- Let go of a hypothesis proved wrong

Men who have excessive faith in their theories or ideas are not only ill-prepared for making discoveries; they also make poor observations.

\- Claude Bernard

HYPOTHESIS

SAFEGUARDS

- Subordinate ideas to facts
- Have multiple hypotheses
- Make special note of data unfavorable to your hypothesis
- Don't embrace conjecture
- Once the experiment begins, throw out the hypothesis

My business is to teach my aspirations to conform themselves
to fact, not to try to make facts harmonize with my aspirations.

-Thomas Huxley

IMAGINATION

PRODUCTIVE THINKING

- Ideas "occur" to us
  - Can't deliberately create ideas
  - May come during
    - reflective thinking
    - daydreaming
- Fertilize your imagination
  - Variety of knowledge and experience
  - Focus thinking
  - Stay curious
- Temporarily suspend judgment
- Use reason to make ideas useful

To be genuinely thoughtful, we must be willing to sustain and protract that state of doubt which is the stimulus to thorough enquiry...

- Dewey

IMAGINATION

CAN BE DANGEROUS

- Don't repress it
  - Risk going astray
- Balance it
  - Criticism
  - Judgment
- Most hypotheses are wrong
  - Check your work
  - Detect and correct mistakes quickly

What merely annoys and discourages a person not accustomed to thinking ... is a stimulus and guide to the trained enquirer.

-Dewey

IMAGINATION

GETTING UNSTUCK

Temporary Abandonment

- Let it be
- Return once old thought associations are less strong
- Flaws in thinking become apparent

In research most of the time progress is difficult and often one is up against what appears to be a "brick wall".

- W. I. B. Beveridge

IMAGINATION

GETTING UNSTUCK

Discussion

- Useful suggestions
- Pooling information may trigger new ideas
- Detection of error
- Stimulating, refreshing
- Escape conditioned thinking
  - Explaining a problem requires clarifying information
  - Questioning by others disturbs our lines of thought

Productive mental effort is often helped by intellectual intercourse.

- W. I. B. Beveridge

INTUITION

SUDDEN ENLIGHTENMENT

- Recognize meaning or significance
- Arises from the subconscious
  - Gut feelings
  - Heuristics
- Capture it

> The really valuable factor is intuition.
>
> - Albert Einstein

REASON

LIMITATIONS

- Logic has very little to do with discovery or invention
  - Logic builds on what is already thought to be so
  - Discovery often requires disregard for current beliefs

Great discoveries have been made by means of experiments devised with complete disregard for well accepted beliefs.

-W. I. B. Beveridge

REASON

SAFEGUARDS

- Don't confuse interpretation with results
  - Recognize that generalizations cannot be proved
  - Don't place excessive trust in generalizations

Research is fundamentally a state of mind involving continual re-examination of doctrines and axioms upon which current thought and action are based. It is, therefore, critical of existing practices

\- Theobald Smith

REASON

INTERPRETING FACTS

- Group facts
- Identify relationships
- Assign significance
- Recognize consequences

Science consists in grouping facts so that general laws or conclusions may be drawn from them.

\- Darwin

REASON

REASON SUPPORTS

- Judging ideas conjured up by imagination and intuition
- Planning experiments
- Deciding what observations to make
- Assessing the evidence
- Interpreting new facts
- Making generalizations
- Identifying applications of discoveries

Although discoveries originate more often from unexpected experimental results or observations, or from intuitions, than directly from logical thought, reason is the principle agent in most other aspects of research and the guide to most of our actions.

- W. I. B. Beveridge

OBSERVATION

EFFECTIVE OBSERVATION

1. Notice something
   - Things of interest
   - Changes in the familiar
2. Assign it meaning
   - Relating it to something else

What is observed depends on who is looking.

- W. H. George

OBSERVATION

DELIBERATE OBSERVATION

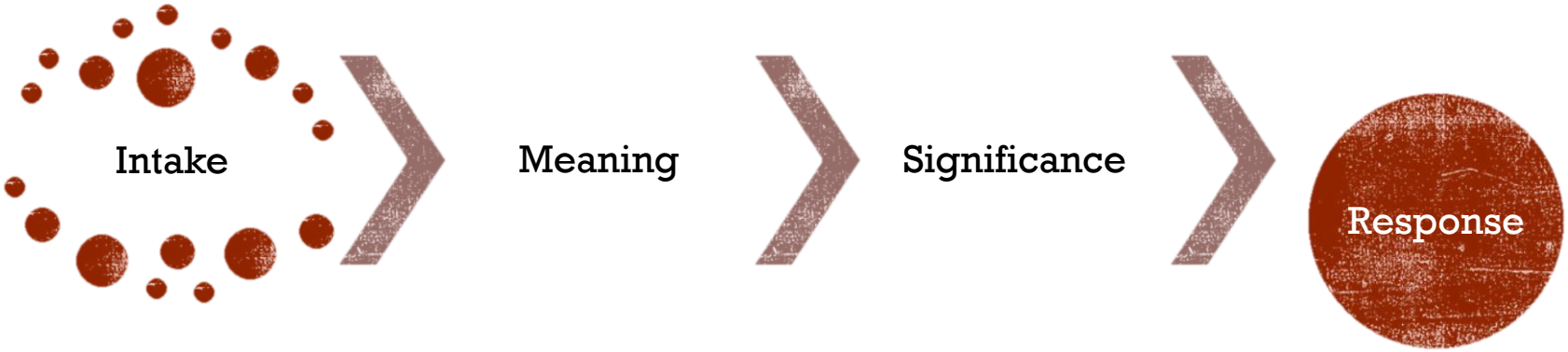
- Explicitly look for expectations
- Keep watch for the unexpected

Effective scientific observation also requires a good background, for only
by being familiar with the usual can we notice something as being unusual or unexplained.

-W. I. B. Beveridge

OBSERVATION

SATIR INTERACTION MODEL



The **common eye** sees only the outside of things, and judges by that, but the **seeing eye** pierces through and reads the heart and the soul, finding there capacities which the outside didn't indicate or promise, and which the other kind couldn't detect.

- Mark Twain

PLANNING

LEVELS

- Tactical
  - Performed by the individuals doing the work
  - Short term
  - One experiment at a time
- Strategic
  - Performed by a larger group
  - Longer term
- Policy
  - Set priorities
  - Allocate resources

Discussions on planning research are often confused by failure to make clear what is meant by planning.

- W. I. B. Beveridge

PLANNING

IS NOT SCRIPTING

- Discovery is unforeseen
  - Infrequently comes from systematic accumulation of data
- Discovery requires
  1. Recognizing the unexpected
  2. Following it up
  3. Concentrated mental effort

The research worker ought not, having decided on a course of action, to put on mental blinders and, like a cart-horse, confine his attention to the road ahead and see nothing by the way.

- W. I. B. Beveridge

PLANNING

ALL PLANS ARE TENTATIVE

- Plan with an appropriate level of detail
- Adapt to discovery
- Communicate deviations from expectations

All plans must be regarded as tentative and subject to revision as the work progresses.

- W. I. B. Beveridge

PLANNING

ALL PLANS ARE TENTATIVE

- Plan with an appropriate level of detail
- Adapt to discovery
- Communicate deviations from expectations

- Planning is iterative

"Since situations (or the information available about them) continuously change, we must continue to adapt our plans as time allows. Planning is a process that should build upon itself—each step should create a new understanding of the situation which becomes the point of departure for new plans. Planning for a particular action only stops with execution, and even then adaptation continues during execution."
- U.S. Marine Corps,
MCDP 5: Planning, 1997

INVESTIGATORS

ATTRIBUTES

- Pioneering attitude
  - Enterprising
  - Adventurous
  - Prepared for difficulty
  - Tenacious
  - Independent thinker
- Insatiable curiosity
  - Dissatisfaction with what is known
- Sometimes difficult
  - Lack confidence in their own views
  - Skeptical of others' views

The most successful scientists are capable of the zeal of the fanatic but are disciplined by objective judgment of their results and by the need to meet criticism from others.

- W. I. B. Beveridge

INVESTIGATORS

PREREQUISITES

- Willingness to work hard
- Intelligence
- Internal drive
- Imagination

It is not the talents we possess so much as the use we make of them that counts in the progress of the world.

- Brailsford Robertson

INVESTIGATORS

DISCOVERING DISCOVERERS

- Attributes of a good investigator are difficult to evaluate
- There is no exam
- Provide opportunity to demonstrate

> Ordinary examinations are not a good guide to a student's ability at research,
> because they tend to favor the accumulators of knowledge rather than the thinkers.
>
> - W. I. B. Beveridge

INVESTIGATORS

ETHICS

- Give credit to whom it is due
- Give generously
- Report sincerely
- Avoid secrecy

In the long run it pays the scientist to be honest, not only by not making false statements, but by giving full expression to facts that are opposed to his views.

- F. Cramer

DISCUSSION

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