Teaching New Investigators to Think:
From Ayn Rand's Objectivism to Sherlock Holmes Deductive Reasoning

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Outline:

Introduction:

Like most technical endeavors, aircraft accident investigation is an evolving practice, as is our understanding of the world around us and how it all works. As technology advances, so should our understanding and ability to analyze. To illustrate, we could start with the accident in which Icarus was fatally injured after an in-flight break-up. The original Greek investigation revealed that Daedalus (Icarus's father) had constructed two sets of wings using feathers embedded in wax so that he and Icarus could escape imprisonment. He had cautioned Icarus not to fly too high because he would pass too close to the sun and melt the wax. Once they launched, Icarus failed to follow the established procedure, climbed too high, and his wings failed. The Greek investigation found that the wax had indeed melted, resulting in the in-flight breakup and subsequent crash. At the time, the Greek authorities didn't have an understanding of basic, higher altitude atmospheric physics, and failed to consider that the air gets colder the higher you go. A revisiting of the accident with today's technology would conclude that, instead of melting, the wax actually became brittle as it got cold, and fractured from the forces acting on the wings, resulting in the inflight break-up and crash. (With a wink at Stephen Barclay.)

I. Abstract

If the goal of accident investigation is ultimately preventing accidents, what does the next generation of investigators need to have in their cerebral investigation toolkit to excel? The historical training paradigm for air safety investigators was to either start with someone near retirement in an aviation-related endeavor and make them an investigator, or take the neophyte and pour in as much short course training as possible. In both cases, much of the expertise an investigator developed was the result of on-the-job training and experience. Is there a better way? Can we apply research and experience gained from other disciplines to create mechanisms and programs to produce "expert" accident investigators much earlier in their investigation career? Teaching the technical and regulatory aspects is straightforward, but are there ways to think and 'see' the make-up of accidents and the relationships that exist at an accident scene? Is accident investigation an "ART" as well as a science? In several ways, the discipline and practice of accident investigation is very similar to the study of history. Both start from the present and work backwards through time to figure out how we got where we are. Both concentrate on establishing facts, events, conditions and circumstances, outcomes and effects, and human actions and inactions. Acknowledging this, what is the minimum level of proficiency needed by a new investigator? Taking this a step further, is there a need to create processes to measure and "certify" accident investigator qualifications and skill levels?

II. The Problem:

Investigators who investigate better, think better, and much of that thinking cannot be taught in a class on accident investigation. Thomas Edison said, "The most necessary task of civilization is to teach people how to think. It should be the primary purpose of our public schools. The mind of a child is naturally active, it develops through exercise. Give a child plenty of exercise, for body and brain. The trouble with our way of educating is that it does not give elasticity to the mind. It casts the brain into a mold. It insists that the child (or adult) must accept. It does not encourage original thought or reasoning, and it lays more stress on memory than observation."

Many brilliant thinkers have pondered this conundrum:

"There is no expedient to which a man will not go to avoid the real labor of thinking." Thomas A. Edison

"There is no short-cut for achievement. Life requires thorough preparation – veneer isn't worth anything." George Washington Carver

"I know that I myself have no special talent. Curiosity, obsession and dogged endurance, combined with self-criticism, have brought me to my ideas." Albert Einstein

"We should remember that one man is much the same as another and that he is best who is trained in the severest school." Thucydides

"The human understanding when it has adopted an opinion, draws all things else to support and agree with it." Francis Bacon

III. Theory: Experts, Thinking and Training

The dominant researcher in the nature of expertise is K. Anders Ericsson. The pre-eminent source concerning the nature of expertise is The Cambridge Handbook of Expertise and Expert Performance, for which Ericsson is one of the editors. Geoff Colvin acknowledges that Ericsson's work of thirty years, on his own and with colleagues, provided the foundation of many of the ideas" in the book Colvin wrote, Talent is Over Rated. This book provides a practical, applicable, and non-academic presentation of the product of Professor K. Anders Ericsson's life work in academia and it provided the impetus for this paper. The following synopsis was synthesized from reading the listed works and, much like Colvin's purpose in Talent is Over Rated, is intended to provide the reader with generalized information concerning expertise applicable to aircraft accident investigation and the training and development of Investigators.

Experts think differently than novices. Experts think conceptually and work from primary concepts that provide context to give meaning to observed details. Similarly, they see details not observed by novices because their uniquely organized memories developed from much combined experiences, alerts them to the potential significance of seemly insignificant details. This realization both emphasizes the need for conceptual training and limits the efficacy of training without experience. It also, within this limitation, supports teaching observation skills and examples of how minute details can communicate much in causation concepts.

Unfortunately experts do not necessarily make good trainers. Along with their unique memory patterns which combine details and conceptual meanings, they may not have retained the linkages they stepped through when they learned what they know. Novices need to be stepped through those links.

It takes a long time to obtain expertise. Ten years is the standard lower threshold to obtain expert status in any field of endeavor. Only those who are dedicated, persistent, striving to improve, and focused or deliberate in their development reach superior or expert status. Most people plateau in their performance when they give up their commitment to seeking excellence or the effort to improve their performance or begin to believe that they have achieved expert status and have nothing left to learn. The most able are in the greatest danger of becoming complacent. The "greats" in any field however, do not become complacent. This could be their most distinguishing characteristic.

Observation skills and critical thinking can and should be taught; though they may to help accelerate the obtainment of expertise, they cannot replace the time, experience, and effort required in developing expertise. This said, the role and importance of logic cannot be overstated. Investigators' thinking about their thinking process while investigating is important and can be taught. It can become the basis for their self-improvement as they acquire experience.

Ayn Rand said that her epistemology was reason. Investigators need to know their basis for determining facts and methods of moving from facts to the determination of the truth concerning an event. Sir Arthur Conan Doyle's character Sherlock Holmes models the epitome of observation and reason. He could be the "ideal" investigator (minus the 5% solution of course.) The book Mastermind: How to Think Like Sherlock Holmes, by Maria Konnikova, provides an enjoyable read that teaches what is currently known in the field of psychology concerning thinking and the mind, using examples from Doyle's Sherlock Holmes stories. Konnikova believes that through Sherlock Holmes, Doyle provides insights into the human mind and illustrates a way of thinking that could be applied to many fields. Scientific method applied to thinking itself! The following is distilled from Mastermind: How to Think Like Sherlock Holmes:

> Our minds naturally wander and attention is a limited resource and it comes at the price of awareness of other things. Also, there is some effort or willful discipline involved in paying attention to something. There is no such thing as free attention; it comes at the cost of what else our attention could have been directed upon. Too often our brains choose what to pay attention to without enough conscious thought. The problem is more of a lack of mindfulness and direction, rather than a lack of attention itself. To some extent directed attentional ability can be increased. There is a 'use it or lose it' aspect to directed attentional ability. To improve our natural attentional abilities we need to direct our thinking to be selective, objective, inclusive and engaged.

Mindset is the beginning of selectivity. This is more than generic observation. We need to form a precise plan to maximize our limited attentional resources. This would include defined objectives and necessary elements for achieving them. There is nothing serendipitous in Holmes' approach to observation.

Objectivity is difficult because we have a tendency to see what we want to or expect to see and we have a similar subjectivity to our thinking itself. To observe well we must learn to separate situation from interpretation. Observations and deductions are separate and distinct steps. Explaining a situation from the beginning out loud to another person can expose where our observations are intertwined with our thoughts and perceptions and can help to disentangle the objective reality from its subjective materialization in our minds. Writing out what we believe we have learned about a situation works even better.

To fully observe we must be inclusive and not let anything significant go unnoticed. Since our attention may shift without our awareness, it needs to be monitored. Also, as we accumulate observations, information is gained to direct attention to confirm or rule out what we have hypnotized. Analyzing whether it is consistent or inconsistent with what we have observed so far and what else we would expect to find and not find to be consistent with what we have observed so far. This creates an awareness of details to look for to confirm or rule out factors.

Engagement is important for observation and thought. Our minds need to be actively engaged. Motivation matters a lot. Without engagement and motivation we become sloppy and can miss critical details. We feel better and perform better when we are motivated and actively involved in an activity, even when doing boring tasks. Strong personal engagement results in observing more carefully and more accurately.

Remarkably, creativity and imagination are important in observation, critical thinking and problem solving skills. Our expectations and experiences affect what we consider possible. "The improbable is not impossible" as Sherlock Holmes said in Chapter 6 of The Sign of Four "When you have eliminated the impossible, whatever remains, however improbable, must be the truth?"

Nothing breeds overconfidence like success. Overconfidence causes us to trust our abilities too much, to underestimate others, and leads to errors in judgment. We need to develop strict thought guidelines to prevent ourselves from becoming complacent.

Dick Wood, in his article "The Basics of Aircraft Accident Investigation" says a big part of it more succinctly, "Regarding knowledge of the accident, much of the process of investigation involves eliminating things that did not happen…" then focusing on finding out what did. We usually refer to this as the "Rule-Out" technique.

Is there such a thing as the “practiced eye?” Most experienced investigators spend the initial period of time at a scene just walking around the accident site, looking for what looks right, and what looks wrong, and triaging how the evidence will be worked. They work from the outside in, from the entirety to the specific, ruling out and ruling in. Is this ability the “art” of accident investigation? If so, can we provide the set of abilities and expertise to accident investigators earlier in their investigation career?

IV. Practice: Current Accident Investigation Training

Given this information, we should ask: what makes up a good aircraft accident investigator? Jerry Lederer weighed in on the characteristics of a good investigator in Flight Safety Foundation Bulletin #1 in May 1948. In an article entitled “Aircraft Accident Investigation” he states the technical qualifications and then says:

> Intellectual honesty, technical competence, tact, natural curiosity, a critical mind that can formulate logical conclusions, imagination and resourcefulness are the essential characteristics of a good investigator.

Sounds very much like a combination of art and science doesn’t it?

For Civil Aeronautics Board Investigators, the U.S. Office of Personnel Management identified “Common Characteristics of Air Safety Investigators” this way in GS-1815, TS-23 in August of 1959:

> The experience, knowledge, and good judgment of air safety investigators have a direct bearing on safety of human life, preservation of economic resources, and the future of aviation. The impact of an accident on the aviation industry and the country is far reaching. Air safety investigators must deal impartially and intelligently with individuals or groups of varying interests in the conduct of their work. They must possess the ability to express themselves clearly on technical matters and be able to work under pressure, often under hazardous conditions, in the investigation of accidents. They must be able to draw conclusions without bias from all the facts, conditions, and circumstances involved in an accident.

Frank Taylor takes it a step further in a previous ISASI Forum paper and defines the “ideal investigator”:

> The ideal aircraft accidents investigator should be qualified, trained, experienced, knowledgeable, observant, inquisitive, dedicated, diligent, open minded, independent, impartial, objective, persistent, patient, logical yet capable of lateral thinking, literate, diplomatic, fit, tireless, stable, level headed and much more. He or she should have humility, integrity, a good and ready sense of humour and be able to maintain a good working relationship with all other parties involved.

The question remains, how can we produce accident investigators with those qualities?

The Flight Safety Foundation offered the first civilian course for aircraft accident investigators in New York in 1946. The topical areas taught were printed right on the certificate and look similar to most of the curricula still in use today.

A review of the current basic aircraft accident investigation professional program courses available reveals that they are all substantially similar, concentrating primarily on regulations, procedures, technical specialty areas common to basic investigation, and report writing. The basic courses are intended to provide knowledge and expertise at the entry level for a new investigator, whether they are a wet-behind-the-ears fresh graduate, or a 30-year airline pilot. Both are neophyte investigators. While most of the educational organizations that do this sort of training provide advanced and specialized additional courses, in most circumstances the vast majority of training and experience is on the job. Note however that the thinking: logic, deduction, and induction (hypothesizing) are apparently presumed to exist and are not taught.

NTSB Training Center **Title Aircraft Accident Investigation** Site documentation and management Operational and mechanical aspects of aircraft performance Turbine and reciprocating engines Fire and explosions Fracture recognition Weather Radar analysis NTSB "party" process Progress meetings Survival factors Human performance Survivor interviews and witness reports Working with local area responders Safety recommendations Case studies include midair collisions, in-flight fires, in-flight breakups and weather-related accidents TWA flight 800 tutorial, examination of the reconstruction of the aircraft wreckage, and a discussion on how the NTSB undertakes major accident investigations	**Cranfield University** **Aircraft Accident Investigation** Legislation and regulation Appraisal of the accident site Disaster response Recovery of wreckage Collection of evidence Accident photography Hazards management on site Wreckage recovery Interviewing techniques Structures and crashworthiness Human Factors for investigators Media management Accident pathology Data recorders and their analysis Analytical techniques Systemic approach to investigation Managing investigations Liaising with victims and their families Relations with the regulatory/interested parties Developing and managing recommendations Report writing Follow-up actions Court procedures for investigators
University of Southern California -USC Viterbi **Aircraft Accident Investigation** Investigations Introduction and History Authority and Theory Principles of Investigation Initial Actions Site Safety Preliminary Field Investigations Investigation of Aircraft Fires Reciprocating Engines and Propellers Gas Turbine Engines Systems Investigation Inflight Breakup and Midair Collisions Technical Assistance Analysis and Report Writing	**Southern California Safety Institute – SCSI** **Aircraft Accident Investigation** The Civil Investigation Process (USA) International Investigation procedures (ICAO) Preparing for Investigation Safety at the Crash Site Priorities and Initial Actions Investigation Techniques for: Engines, Structures, Fire, Aircraft Systems, Instruments, and Recording Devices Wreckage Recovery and Reconstruction Photography and Diagrams Midair Collisions Interviewing Witnesses Behavior of Materials

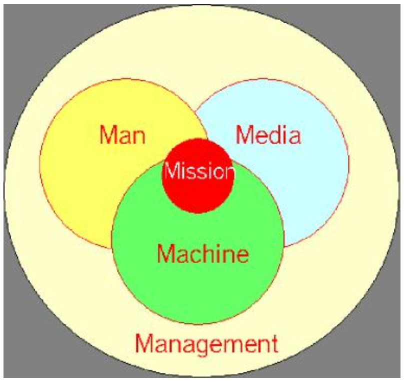
Flight Data Recorders Cockpit Voice Recorders Technology Understanding Aircraft Stability Wind Shear- Aerodynamics Metal and Composite Materials Types of Material Failures Identifying Failures in the Field Human and Biomedical Factors Human Factors The Behavioral Anatomy of an Aircraft Accident Aeromedical Role in Investigation Media Relations Overview of Strategy Message Development and Thought Process Use of Techniques, Practical Application Critique and Analysis of Potential Situations The Role and Reality of Media in Accident Investigation	Using the Global Positioning Satellite (GPS) system Aircraft Performance Factors Computers and Simulation Human Factors and Accident Pathology Analytical Techniques Reporting Requirements Construction of Reports Investigation Management
Embry-Riddle Aeronautical University **Aircraft Accident Investigation** Introduction to Investigation: The 5-Whys History of Accident Investigation Who's Involved: the NTSB, FAA, ICAO, others Accident Scene Safety Field Investigations Evidence Documentation Accident Photography Electronic Witnesses: Flight Recorders, ATC, etc. Witness Investigation Operations Investigation Powerplant investigation Systems/instruments Investigation Structures Investigation Fire Investigation Accident Reconstruction Analysis and Report Writing Legal Aspects Laboratory Exercises	**IATA** **Aircraft Accident Investigation** Aviation organization, regulatory agencies and management systems Introduction to ICAO SARPs Regulatory overview and Annex 14 SARPs Investigation authorities State obligations Participating in an investigation Right and obligations of participants Conducting and investigation The airline advisor and expert Airline support functions Accident reporting Safety recommendations Airline go-team

V. Improvements to and Limits for Accident Investigation Training

One of the greatest gaps seen in many students that come through Embry-Riddle Aeronautical University's (ERAU) programs is the lack of ability to view the entirety of the accident evidence as a combined, interrelated, and very interactive system. The thought processes that are used by an investigator who is only schooled or "book smart" but who is lacking experience, tend to focus on the pieces rather than an understanding the totality. The other big gap that is observed relates to the ability to see what is right in front of them.

The Robertson Aircraft Investigation Lab at ERAU Prescott Campus has been enhancing several of their accident scenarios to incorporate practice intended to address both of these “gaps”. For example, one of the scenarios involves the crash of a glider. The aircraft is fully laid out, with ground scars, tree strikes, and even simulated blood in the cockpit. In the area just behind the pilot’s seat, there is a segment of aluminum tubing, clearly marked “oil.” Most students never see or question that anomalous piece of evidence and are quite surprised when shown it. Another scenario involves an R-44 helicopter that experienced a dynamic rollover and post-crash fire. The site has been used for every professional program course run by ERAU, as well as for the undergraduate and graduate academic investigation classes, for the last 2 years. Thus far, only 2 students have observed that the wrong engine is installed in the scenario. There is a 4-cylinder O-360, rather than the 6 cylinder IO-540 that should be there. Again, students are surprised when this is pointed out to them.

The Robertson Aircraft Investigation Lab at ERAU Prescott Campus has also begun to incorporate “deliberate practice” (a phrase coined by Dr. Ericsson) exercises into the accident investigation curriculum, using smaller, more complex scenarios designed to instill the “system” thinking techniques described previously. These scenarios are intense, focused on a very specific part of the investigation process, and are designed to teach the students to think outside the box to solve problems. The overall safety curriculum itself is moving toward incorporating critical thinking and logic classes as part of the core program to improve reasoning abilities. Also, to instill the “global view” of the accident process, models like C.O. Miller’s 5-M’s model below (Management, Man, Machine, Media, Mission), is being applied to solving specific accident scenarios as a “deliberate practice” exercise for the investigation students.



Other in-class possibilities to improve observation and critical thinking abilities include using games like Mastermind and Sim City, and projects like Pascal’s Candle, or such, as exercises. The practical limitations making such thinking training available for investigators already investigating are, mostly the time, money, and effort to do additional training. However, those responsible for managing aircraft accident investigation functions would wonder “is there a need for deliberative practice concerning thinking skills” and “do these ideas provide an important and useful tool for the investigator’s mental tool box?” Perhaps the answer is elementary dear reader!

Some of the issues identified in Section II above concern aspects of the development of critical thinking skills that can only come with experience. This suggests that the orchestrating of the development of experience after initial training and the mentoring during the early development of experience would accelerate the development of expertise to some extent.

Another factor to consider is that teams do a much better and faster job correctly analyzing an accident than solo investigators. Participating in and studying the results of small team investigations usually proves this to be true. Our thinking is more disciplined when we speak it out in collaboration with another party. The more eyes there are the more chance for observations to be made. The more diverse the experience of the group, the less perception bias would occur. On the creative side, teams or partnering contributes to the development of ideas concerning what the observations could mean. At a minimum it could be concluded that new accident investigators should be teamed up with experienced, but not necessarily the most expert investigator, with the more experienced investigator tasked to think out loud for the benefit of the less experienced investigator.

Our learning is never complete. Ultimately, it is the consummate professional that does not become complacent, who does not become too confident, who continues to think critically about their thinking, who does not know it all, who will become the most expert and make the best aircraft accident investigator. It is our hope that this article has contributed to your thinking about your thinking, no matter how experienced of an accident investigator you are. And if you are, or become responsible for, the training and development of aircraft accident investigators, that it will help you to turn out a better investigators.

Beyond all the previous discussion, the question arises whether there is a need for some form of "certification process" to ensure a minimum level of proficiency for aircraft accident investigators? Currently there is none. Chuck Miller was always a proponent of such certification. The issue with certification has merit concerning ensuring minimum ability. Should some group like ISASI consider certification?

But shifting back to the focus of this paper, Sherlock Holmes was not credentialed and Inspector Lestrade was. We all, no matter where we are in our experience level and the development of aircraft accident investigation expertise, can improve by engaging in deliberative practice concerning our observation and critical thinking skills. Thinking about our thinking, or meta-cognition is possibility the single most significant thing we can do to improve our performance as aircraft accident investigators.

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