4 Differences in Physician, Engineer, and Life Scientist Training, Practice, Problem Solving, and Approach to Failure

Daniel Buckland, MD, PhD, MS and Sarah Miller, PhD

Abstract: Many of the failures in communication among physicians, engineers, and life scientists may be due to the differing ways that they approach problems. More than mere personality differences, physicians, engineers, and life scientists are trained with different problem-solving philosophies and strategies. This chapter discusses these differences, provides several example problems that characterize these three different ways of thinking, outlines the corresponding differing approaches to failure, and concludes with a glossary of some terms that are used in different ways across these three fields.

Keywords: physicians, engineers, and life scientists, problem-solving, failure analysis, communication

Note: Portions of the following chapter were published as part of a similar series on Medgadget.com and are reproduced with the permission of the publisher.

Differences in Physician, Engineer, and Life Scientist Training, Practice, Problem Solving, and Approach to Failure

Introduction

Inherent in the complex problem solving required in human exploration of space are interactions between physicians, engineers, and life scientists. Conventional wisdom suggests that when one corrals several intelligent individuals in a room, progress is made. However, as the information and theoretical examples below demonstrate, when differently trained individuals come together to solve a problem, each has different assumptions about the problem-solving framework that will be employed–and, typically, an individual does not realize that these different frameworks exist. Greater understanding of the framework and context of each profession may reduce interdisciplinary misunderstandings; allow complementation of each profession's strengths and weaknesses and ultimately leading to more efficient collaborations while a combination of these three different approaches may yield more robust solutions.

The three types of problem solvers presented below–physicians, engineers, and life scientists–are meant as archetypes. Of course, individuals would use a mix of these problem-solving methods based on their knowledge and experience, but they may never have received formal training in methods other than the ones specific to their field of expertise. These simplistic descriptions are not meant to imply that all individuals in each of the described groups are alike or that they are incapable of utilizing multiple problem-solving frameworks. These archetypes were developed based on the experiences of the co-authors, who have a MD, a PhD in Aeronautics and Astronautics, and a PhD in Biochemistry between them with relevant academic, government, and industry exposure.

The Three Types and their Approach to Problem Solving

The Physician

Physicians are trained in medical school to think about differentials and categories. A patient's presenting signs and symptoms are processed, then historical information is used to determine the most common diagnosis associated with that dataset, with highly dangerous but less common diagnoses also included. More complicated tests are applied based on both the common and dangerous potential diagnoses, and then treatment is often based on the outcomes of those tests. This is a categorical approach to problem solving; the physician tries to determine what category the patient belongs in, and then treatment is based on the assigned category. This is a very efficient system when a patient has a problem that has been encountered before, and when there exists a dataset to which the patient can be matched. Often, a thorough dissection of the problem is not even needed because this problem-solving approach is based on probabilities. Computer programmers would refer to the physician's approach as searching a '*known set,'* which is often the fastest way to find a solution if the solution is in the set. However, when the patient has a novel problem, this is a very inefficient approach, as the physician moves to less and less common solutions; that is, the known set approach is the slowest if the solution is not in the set, as all possibilities must be excluded before determining that the answer is not there.

The Engineer

If the physician is trained to solve a problem by applying a known set of solutions that can be applied then the engineer is trained to take a known solution and then use that as a starting point to formulate a more specific solution that applies to the discrete problem at hand. Both can be compared to the life scientist starting with a new set of hypotheses for each problem. Like the life scientist, the engineer tries to break down the problem; however, the engineer does not break it down all the way if this level of detail is not required to solve the problem. Thus, the engineer is not always looking for root cause when creating a system or novel solution. Instead, the problem is only simplified to the degree required to yield a solution that works with the least amount of change from the current paradigm (however, see below for further discussion of how engineers determine root cause in failure analysis). Going back to our programming analogy, this is a '*local search*', in that the engineer is looking for an efficient way to find an optimal solution. The search is completed as soon as more solutions do not improve on an already established solution, but may miss a more optimal solution that is not close to initial parameters of the search.

The Life Scientist

In contrast to the physician and engineer, who each have the goal of producing specific desired outcomes, the goal of the life scientist is to thoroughly understand a biological process or system that already exists. The life scientist is trained to explore biological problems using testable hypotheses and, critically, control experiments to isolate all the key components of a biological process and determine how they work together to facilitate that process–in other words, application of the scientific method to understand how living systems work. Addressing problems in this way is more resource- and time-intensive than the physician's method, but if the proper hypotheses are posed, this system can handle a broader range of problems and generate new data that are applicable to other problems. Programmers would call this approach a *'global search,'* which is often the least efficient way to find a solution, but the solution found would have a higher chance of being the optimal solution because (ideally) it considers the most information.

Three Approaches to Three Problems:

This section poses a problem and then describes how the three archetypes described above could approach solving the problem. Each one is meant to show that none of the problem-solving types is inherently better than the others or that there is a right or wrong way to approach these problems. Instead, these scenarios are meant to show that, due to the nature of the training and problem-solving approaches each archetype utilizes, they are each differently suited to different types of specific situations.

1) Patient A started coughing this morning. What should she do about it?

***The Physician* –** What are the most common causes of cough? What are the deadliest causes of cough? For this patient's age and medical history, which of those causes are most likely? Has she been treated successfully for a cough in the past? Would any test results change the treatment plan? Treatment will be based on what has historically worked best for the most likely diagnosis.

***The Engineer:* –** What is different now than when she was not coughing? What was she doing this morning when the cough started? If she tries one treatment and gets a little better, then she should use more of it to get a greater effect.

***The Life Scientist* –** If it is infectious, what is causing the infection? If we find what is causing the infection, do we know how it is causing the cough or irritation?

In this case, the physician probably has the fastest and most efficient route to diagnosis and treatment plan if there is a common cause for the cough. The life scientist's method, when it eventually gets to a treatment, will have produced a lot of information, but it would take a longer time and be very resource-intensive. However, if there is an uncommon cause for the cough, the life scientist's method will be more likely to find it. The engineer's method could work as well but does not use the shortcuts of the physician or the robust strategy of the scientist.

2) **Patient B had her gallbladder removed by Dr. C. Dr. C performs a laparoscopic procedure, but the tools she uses do not work the way she wants them to and she feels that she spends too much time struggling with the equipment rather than performing the procedure. Other surgeons say they have the same problem too. What should be done?**

The Physician: What have other surgeons done to compensate for the unwieldy tools? Do any of those methods fix the problem of taking too much time struggling with equipment?

The Engineer: What exactly does the surgeon like and dislike about the system? How could we modify the current system to keep the benefits and lose the difficulties?

The Life Scientist: How would we, from first principles, design a novel laparoscopic system that does not have those problems?

For this issue, the engineer probably has the most efficient approach. Rather than starting from scratch like the life scientist, or treating the problem as fixed like the physician, the engineer's approach looks for the simplest novel solution using the current context.

3) **Patients D, E, F, G and H all have a form of slow-growing cancer that no one has seen before. The patients are all related, but they do not carry any of the genetic mutations known to be associated with other cancers. What type of therapy should be used for patients with this disease?**

The Physician: – Of all the cancer types known, which one is the closest to this one? How is that cancer treated? If that does not work, what is the next closest match? How is that cancer treated?

The Engineer – What makes this cancer different than the closest match that has been treated in the past? Can we use that difference to modify the treatment plan?

The Life Scientist – How does this cancer work? What genetic mutations and/or environmental factors are driving the cancer cells to proliferate? Can that information be used to determine how to selectively kill the cancer cells without harming healthy cells within the patient?

In this case, because there exists very little information about the problem itself, the life scientist's method is probably the best approach 'scientifically' to take for identifying a long-term plan for treating patients with this disease. However, the physician's method arrives at a treatment faster, but it more uncertain and may cause more pain and discomfort with less overall benefit if the closest analogy has a very different root cause. The engineer method looks at these differences to try to find a solution.

Three forms of Failure Analysis

Another important different difference in training and practice between the three archetypes is how they approach failure analysis. Failure analysis is more of an introspective skill set than problem solving or design, one that entails a different set of biases. Something possibly went wrong, and the task is to find the error, adding a dimension of responsibility that the above discussion of problem solving does not necessarily entail. The assumptions of personal accountability and responsibility differ among the archetypes, and this can affect how they each approach problems or reviews of another group's performance. Especially in multi-disciplinary endeavors where multiple teams and individuals are responsible for different system components, defending the decisions leading to an error can be an important consideration when contemplating a new approach or idea. How will they defend this decision to peers and outside reviewers if things do not go well? Moreover, in what environment will they be defending it? Much like problem solving, understanding the differing approaches to failure analysis can improve collaboration and prevent misunderstandings that are likely to occur when reviewing errors or outcomes in a multi-disciplinary group.

The Physician – When physicians talk about failure or mishaps formally, it is usually in a meeting called "Morbidity and Mortality" (M&M). The M&M is considered so important to the medical profession that the Accreditation Council for Graduate Medical Education (ACGME), the organization responsible for accrediting medical residency programs in the United States, requires M&M sessions to be held regularly during a physician's training. In an ideal M&M meeting, a case that resulted in an undesired outcome is presented to the entire medical staff of a department or organization. Then the group will ask questions of the responsible staff to try to determine whether the outcome was avoidable and, if so, where the fault lies. Many states specifically[1] exempt these meetings from being used to determine legal liability, emphasizing that the purpose of an M&M is not assignment of blame but, rather quality control and education. In these meetings, blame is often assigned and also often accepted during peer group discussions. While the precise M&M meeting interpersonal dynamics depend on the level of respect within the group, an accusatory atmosphere is typically prevented through a baseline assumption of physician competence. In contrast to the other two groups, physicians are usually more likely to give their colleagues the benefit of the doubt. The questions raised during these sessions are highly collaborative in tone, and participants often precede their queries with a statement that they do not know what they would have done differently in the same situation. However, this approach can be limiting to new ideas. Often it is easier to defend a choice if it followed the standard of care, even if that choice was objectively worse for the patient.

The Engineer – Once again, the engineer functions somewhat midway between the physician and the life scientist. Though the nomenclature differs between industries and organizations, most engineering groups have some form of weekly or monthly "incident reviews (*see inset*)." In these meetings, "failure" can mean anything from a catastrophic collapse of a whole system to a validation test in which some components performed outside of specifications. In contrast to the engineer's approach to problem solving, here, the engineering group is focused on finding the root cause of the error. Often, a no-fault approach is used to facilitate individuals to speak up without fear of blame. In systems involving human users, many engineers are trained to follow a "Swiss cheese" model of fault analysis. In this model, the engineer acknowledges that it is rarely one error that causes a failure, but rather, several errors, each from a different source, typically align to allow the failure to occur. The underlying assumption of this model is that failure is inevitably going to occur at some point, so it is not appropriate to level all the blame for failure at the final fault when all the precipitating errors are to blame as well. In

> Other names are Lessons Learned, Fault Tree Analysis, Wishbone, or Root Cause Analysis depending on the method used. Ironically, engineers in the non-medical field often call them "Postmortems."

[1] Connecticut's Medical Liability laws (https://www.cga.ct.gov/current/pub/chap_368a.htm#sec_19a-17b) (Accessed July 20, 2017)

these meetings, like physicians, engineers assign responsibility but not blame. Like life scientists, they are interested in the root cause of a failure and do not begin with an assumption of competence. However, as mentioned, in the engineer's formulation, it is not necessarily the fault of an individual if they did not exhibit competence in a given situation. In these incident reviews, meetings are usually kept orderly by a top-down approach, and it is considered the responsibility of the program manager or system engineer to prevent the meetings from becoming acrimonious.

The Life Scientist – Most scientific groups have some variation of a weekly "lab meeting." In these small group sessions, a group member will often present some in-progress project or recent data. Confusing results and unexpected data are presented, with the hope that the group can provide technical support, mechanistic insights, or advice for future experiments. If the results are unexpected, it is common to question whether the experiments were performed properly, and if all the appropriate controls were conducted to establish the validity of the tests. Here, the questioners often do not assume the competence of the presenter without data to support that the techniques were properly executed. This is one form of "peer-review"– or the quality control process that occurs in science. In fact, the motto of the United Kingdom's Royal Society is "*Nullius in verba*[2]," which roughly translates to, "does not take anyone's word for it," including your closest colleagues'. These meetings can become very heated, but what, theoretically, stops someone from being too confrontational is that they know they must stand in front of the same group at some point in the future and present their own data. That said, most academic scientists can usually tell you a story of a lab meeting where someone went too far and a graduate student or postdoctoral fellow was found crying in a cubicle later.

The differing methods in failure analysis can often be seen in the question and answer sessions following presentations at large national meetings, which is where a lot of physicians, engineers, and life scientists first encounter one another outside of their working groups. Anecdotally, questions at engineering conferences tend to be more confrontational than at medical conferences, but less confrontational than at scientific conferences. While these meetings do not constitute failure analysis, the peer-review aspect of such meetings renders the tone of questioning critical at times, and discussion tends to follow the framework of each archetype's trained method.

Archetype Vernacular Guide

Understanding the differences in problem solving and failure analysis are important for a broad view of how the different archetypes can think differently. One specific way in which these differences manifest is when physicians, engineers, and life scientists use the same words to mean very different things. Clearly, this can lead to confusion and misunderstandings. In the examples below, each term is followed by the meaning of a common use of the term according to each archetype and then an example sentence for context.

Test:

Physician: examination of symptoms or disease presence

He was tested for high blood pressure.

[2]Royal Society. http://royalsociety.org/about-us/history (Accessed July 20, 2017)

Engineer: determination of limits

The beam was tested to failure.

Scientist: experimentation to obtain evidence in support of a hypothesis

The protein-membrane interaction hypothesis was tested.

Risk:

Physician: effect of pre-existing factors on chance of disease

His risk of heart disease is increased by his father's death from heart attack.

Engineer: probability of a particular outcome

The risk of structural failure of this beam at 30 lbs is 80%.

Result:

Physician: presence or absence of disease or condition

The results of the CT scan show a pulmonary embolism.

Engineer: capabilities of a design

The results show the wing can provide lift without structural failure from 50 to 300 mph.

Scientist: experimental evidence

Our results show that the protein interacts with the membrane.

Failure:

Physician: unsuccessful treatment

The blood pressure medicine failed to prevent a heart attack.

Engineer: exceeded limitations

The beam failed at 40 lbs.

Scientist: unexpected findings or technical difficulties

The protein-membrane experiment failed to support the hypothesis.

The experiment failed due to incorrect salt concentrations in the buffer.

We hope that the above discussion will help inform future discussions among physicians, engineers, and life scientists. As each field continues to train and practice in their own paradigms, there will continue to be differing approaches to problem solving, failure analysis and even basic vocabulary. However, appropriate recognition and use of these differing approaches by management and collaborators can lead to a more thorough common understanding and robust solutions by multi-disciplinary teams.