Title
PDSA Problem Solving: With a gentle introduction to double-loop learning, program theory, and causal graphs

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PDSA problem-solving—with a gentle introduction to double-loop learning, program theory, and causal graphs

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1 Introduction

Humans have three core cognitive-behavioral processes [1]: *deciding*, *acting*, and *learning*. *Adaptation* comes from adjusting our decisions and actions based on what we learn. *Improvements* are adaptations that make things better. These processes — mediated by *emotions* — are fundamental to all human activities, and form the basis for innovation and continuous improvement.

learning organization

To become a *learning organization*, we must ensure:

1. **decision quality** (decisions, supported by data science)
2. **strategic execution** (actions; includes project and porfolio management)
3. **performance improvement** (learning; improving processes and results, achieving goals)
4. **positive and safe environments** (emotions; for examples, see [1,2])

population health

Population health is "a systems framework for studying and improving the health of populations through collective action and learning" [3]. *Lean practice* is "systematically developing people to solve problems and consuming the fewest possible resources *while* continuously improving processes to provide value to community members and prosperity to society" [4]. *Population health lean* (PHL) is a transdisciplinary[1] management system for continuous learning, adaptation, innovation, and improvement based on lean thinking and practice, the PHL leadership philosophy (Figure 1), and complementary frameworks[2] [1].

population health lean

lean thinking

Lean thinking consists of three components that build upon each other:

1. Plan-Do-Study-Act (PDSA) problem-solving,
2. validated learning, and
3. A3 reporting.

Validated learning[3] is rapid PDSA cyles with a purposeful goal. We embrace "failures" as learning opportunities ("fail fast, fail cheap, fail forward"). A3 reporting uses a single A3-sized paper[4] to summarize the collaborative PDSA problem-solving. PDSA is at the core of lean thinking, the PHL leadership philosophy (Figure 1), and leader standard work.[5] Because of its central importance, this paper covers PDSA problem-solving; for other topics see [1].

In this paper, "problem" is a general term that includes needs, problems, or opportunities. A *need* is something that is considered essential (e.g., human drives). A *problem* is something

[1] Different disciplines working together to create new conceptual, theoretical, methodological, and practice innovations that integrate and move beyond discipline-specific approaches to solve common problems.
[2] For example, design thinking, lean startup and production, and collective impact methods.
[3] Also called the "improvement kata."
[4] Or 17in × 11in paper.
[5] Starting with self, leader standard work is developing people to solve problems and improve performance.

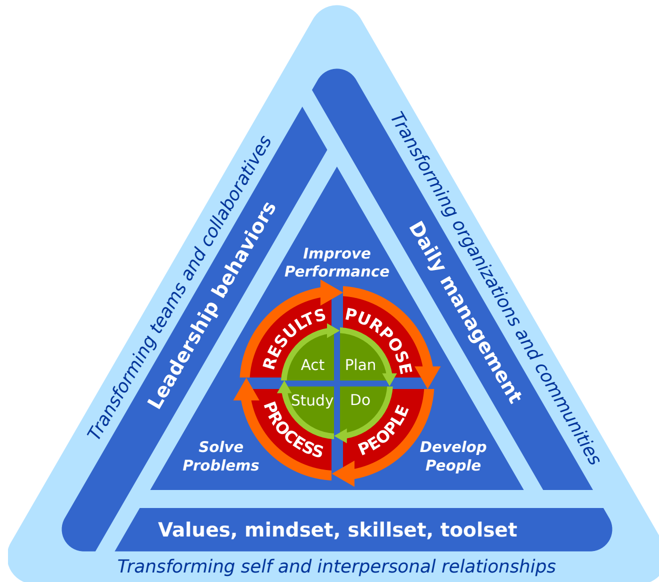

Figure 1. The population health lean leadership philosophy focuses on transformation with PDSA problem-solving that aligns to purpose, people, process, and performance.

that is not meeting an expectation, including its root causes. An *opportunity* is the possibility to pursue something new or different, and may include a new way to fulfill a need or fix a problem.

In this paper, "problem-solving" is a general term for seeking, finding, and defining needs, problems, or opportunities; for discovering and testing root causes; and for discovering, designing, testing, and selecting creative, doable solutions. Problem-solving goes beyond fulfilling needs and fixing problems, but includes creativity, innovation, and pursuing new aspirational goals.

2 What is PDSA?

PDSA stands for Plan-Do-Study-Act. PDSA is the scientific method and we have been using it all of our lives. PDSA thinking and problem solving is part of human nature: it is how we try things, learn, and adapt. Unfortunately, many believe, mistakenly, that the scientific method is only for scientists. By recognizing that we are already scientific thinkers we can improve our daily decision-making, problem-solving, innovation, and performance.

PDSA is both simple and profound. In practice, PDSA is a learning cycle based on experiments. PDSA has two distinct, but related, purposes:

- knowledge deployment: experiments to test and spread a new practice
- knowledge discovery: experiments to test and spread a new theory

theory

A *theory* is a explanatory (cause-effect) model which may be explicit, invisible (e.g., cultural norm), or implicit (i.e., unconscious; for example, implicit racial bias). In *knowledge deployment* we experiment to test a new practice idea without challenging or testing the underlying theory. We hypothesize the new practice is better than the old. Our intent is to improve practice. In *knowledge discovery* we experiment to test a new theory. We hypothesize the new theory is valid (or invalid). Our intent is to improve theory. Linking the concepts of knowledge discovery and deployment promotes translational research and double-loop learning (see p. 3).

knowledge deployment

knowledge discovery

"The secret to PDSA is prediction."

PDSA can be used "as is": just plan, do, study results, and act on what you learned. *The secret to PDSA is prediction*: "People learn better when they predict. Making a prediction forces us to think ahead about the outcomes. Making a prediction also causes us to examine more deeply the system, question or theory we have in mind" [5]. "We will learn much more if we

Table 1. PDSA for daily problem-solving[a] (and variants)

PDSA	Core activity	Design thinking	Lean startup
Plan	Define-Decide	Empathize	↓
	Design-Decide	Define	↓
	Predict	Ideate	(Ideas)
Do	**E**xperiment	Prototype	Build (product)
	↓	Test	Measure (data)
Study	**L**earn[b]	(learn)	Learn
Act	**I**mprove[c]	(improve)	(improve)

[a] Every day think: **P**redict – **E**xperiment – **L**earn – **I**mprove (PELI)

[b] Mindful observation, Reasoning, and Reflection

[c] Adopt, adapt, or abandon ("pivot or persevere")

write down our prediction. Otherwise we often just think (after the fact), 'yeah that is pretty much what I expected' (even if it wasn't)" [6]. We *learn* by experimenting to close the knowledge gap between prediction and results. We *improve* by using what we learn to close the performance gap between current and desired results.

We can improve PDSA by understanding its core activities (Table 1) which are not always obvious:

1. *define* (includes seeking, finding, and understanding) the problem, and set objectives;
2. *design* processes (a) to discover, test, and prioritize root causes; and (b) to discover, test, and prioritze possible solutions;
3. *decide* on creative, doable solutions to prototype and test;
4. *predict* the results (outputs, outcomes), and conduct *experiments*;
5. *learn* by observing results with mindfulness (focus, free of bias and prejudgment); by reasoning using sound logic; and by reflection (looking for deeper meaning); and
6. *improve* by adopting, adapting, or abandoning the option for the next iteration.

Also included in Table 1 are PDSA variants from two enormously effective, complementary, and popular approaches called **design thinking** and **lean startup**. To learn more see [1] or study references [7–10]. The critical point is that *all these methods use the scientific method* (PDSA) for finding problems, discovering root causes, and designing, testing, and spreading effective solutions.

3 What is double-loop learning?

Incremental performance improvements occur by improving practice. All practices have underlying cause-effect assumptions, also called theories or schema. The typical approach is to use PDSA cycles to test and adjust practice improvements. We *plan* to test a practice innovation, we make a prediction and test (*do*) the practice innovation, we *study* the results, and we *act* on what we learned. This leads to incremental practice improvements.

Chris Argyris called this *single-loop learning* [11–13]. He recognized that PDSA can also be used for *double-loop learning* which can lead to new theories and breakthrough performance improvements. Figure 2 depicts PDSA with single-loop and double-loop learning. For example, when efforts to improve a practice are failing (unsatisfactory results), we have two choices:

- continue attempts to improve the practice (single-loop learning; possible incremental improvements), or
- consider improving the theory (double-loop learning; possible breakthrough improvements)

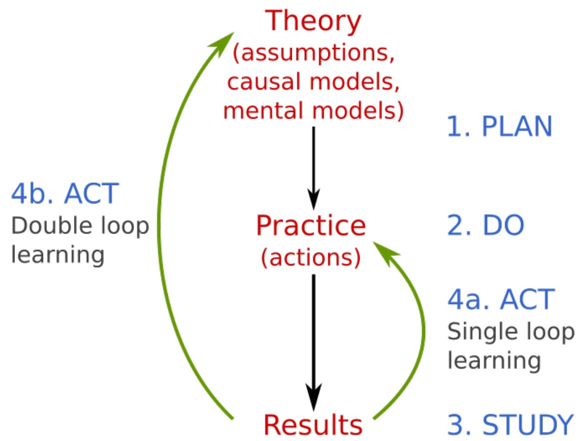

Figure 2. PDSA single and double-loop learning. Most improvement projects focus on single-loop learning. However, when practice results are not improving, question and test your assumptions (double-loop learning).

Double-loop learning makes these possibilities explicit and encourages innovative (breakthrough) thinking. We aspire to be creative PDSA problem-solvers where expressing, challenging, and testing underlying assumptions (theories) is second nature. This requires intellectual honesty, courage, and curiosity.

Figure 3 depicts a well-known, historical example of single and double-loop learning with Olympic high jump performances [14]. Single-loop learning led to incremental improvements during the "Scissors" era. However, when a new theory of high jumping emerged (i.e., "Western Roll"), we witnessed breakthrough improvements, followed again by incremental improvements until new theories emerged ("Straddle," "Fossbury Flop"). Double-loop learning is powerful but requires awareness of its availability. We also need better conceptual tools to discuss theory. For this, we dive into program theory next.

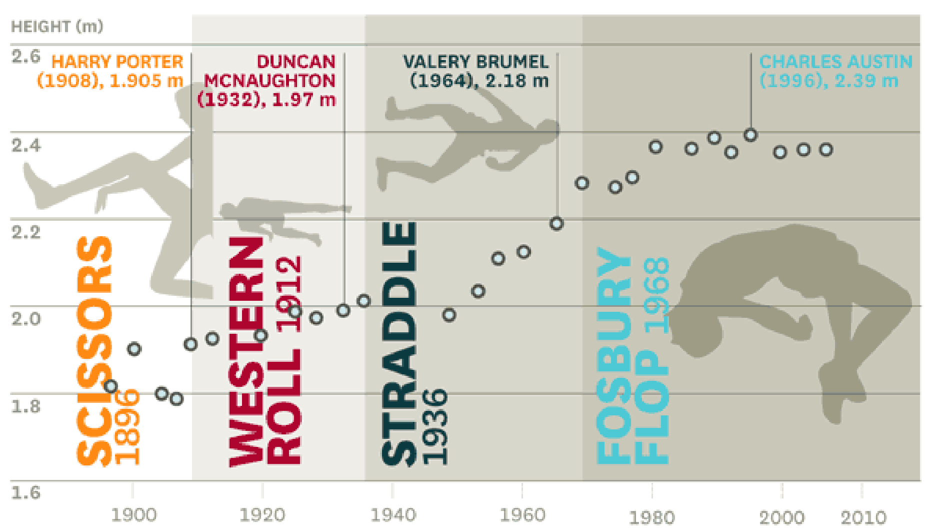

Figure 3. Olympic gold medal winners in the high jump (Olympic Games were not held in 1916, 1940, and 1944).

4 What is program theory?

Program evaluators have a holistic, practical view of theory called "program theory." Adapting from Funnell and Rogers [15], *program theory* consists of three components:

- theory of *causation*,
- theory of *change*, and
- theory of *action*.

Before we intervene, what is our underlying causal assumption (theory of causation)? For example, the tobacco industry targeted youth with advertisements to induce them to "smoke" electronic cigarettes. What intervention strategy will we select (theory of change)? For example, we might select changing "social norms" as our behavioral intervention strategy. What specific activities will we deploy to activate our theory of change (theory of action)? For example, we might select to launch a "social marketing" campaign to change social norms around e-cigarettes. Our program theory should be stated clearly and make intuitive sense to primary stakeholders, including our staff.

In contrast, behavioral scientists use the term "social and behavioral theory" for complex psychosocial constructs based on extensive academic research and validation [16]. The theories can be categorized into

- individual health behavior theories;
- social, cultural, and environmental theories; and
- multi-level theories.

In my experience, some public health staff have limited experience with these behavioral models; they tend to rely primarily on biomedical, epidemiologic models (exposure → disease), and less on complex psychological, social, and behavioral theories. In any case, whether stated or not, *all public health interventions have a program theory* (theory of causation, change, and action).

In order for us to take advantage of double-loop learning, to improve our leadership coaching and teaching, and to improve our leader standard work, we must get in the habit of (a) stating our program theory, and (b) using humble inquiry to ask our staff about their program theory.

5 Case scenario for reflection and discussion

You are the new health educator for the local school district. The superintendant wants to increase student **vaccination rates**. You survey the parents about their level of concern regarding vaccines (adverse events, "autism", etc.). You hypothesize that you can increase vaccination rates by providing scientific facts about vaccine safety, including debunking myths, such as "vaccines cause autism." Your team decides to launch a targeted **social marketing** vaccine safety campaign.

Epidemiologist thinking (Dr. Juan Nieves)

A medical epidemiologist, Dr. Juan Nieves,[6] was assigned to assist you. His working hypothesis is that parents who are exposed to the vaccine safety campaign (yes vs. no) are more likely to vaccinate their children (yes vs. no). He proposes to conduct multivariate regression analysis in SAS to control for "confounding," and, possibly, "interaction," but needs for you to pay to renew his expired SAS license.

Health educator thinking 1 (theory of causation)

You believe that **parental knowledge** gaps about vaccine safety lead to an increase in **parental concern** and a decrease in **vaccinated children**. You recognize this as your **Theory of**

[6] Dr. Juan Nieves is a fictitious character; any resemblance to anyone you know is purely coincidental.

Causation (Figure 4).

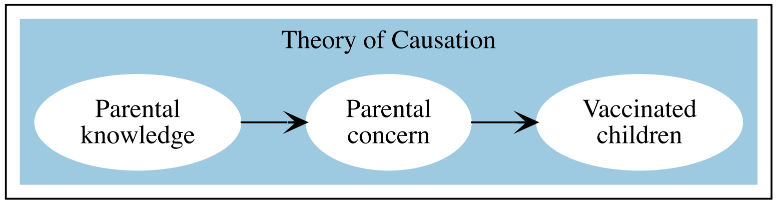

Figure 4. Causal graph depicting the Theory of Causation

Health educator thinking 2 (theory of change)

You hypothesize that if you narrow **parental knowledge** gaps about vaccine safety, **parental concern** will decrease, and the number of **vaccinated children** will increase.

After reviewing many options, your team selects transforming **social norms** as the primary strategy to narrow **parental knowledge** gaps. You recognize this as your **Theory of Change** (Figure 5).

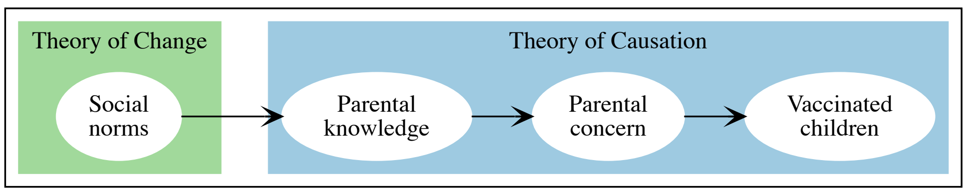

Figure 5. Causal graph depicting the Theory of Change, and of Causation

Health educator thinking 3 (theory of action and program theory)

Of all the available interventions to impact **social norms**, your team selected to implement a **social marketing** vaccine safety campaign. You recognize this as your **Theory of Action** (Figure 6) and, together with the theory of change and of causation, is called the **Program Theory** (Figure 6). As a health educator you recognize that, whether stated or not, *all public health interventions have a program theory* (theory of causation, change, and action). You also recognize that program theory aligns with **Results-Based Accountability** (RBA) [17].[7]

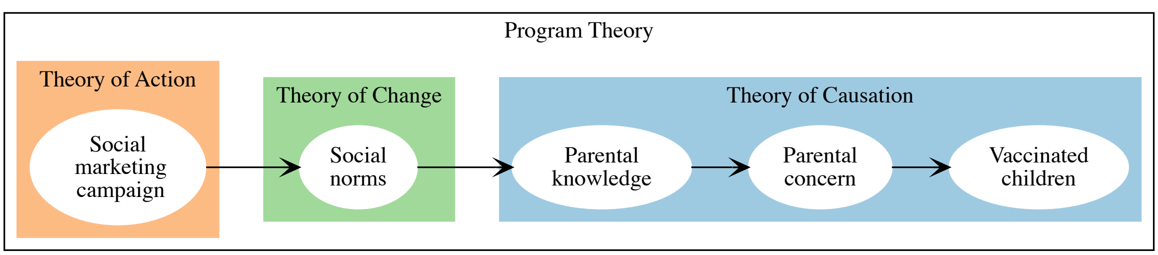

Figure 6. Causal graph depicting the Theory of Action, of Change, and of Causation (collectively called Program Theory)

[7]Program theory: (a) theory of causation (RBA: What is the story behind the curve? [root causes]); (b) theory of change (RBA: What works to do better? [strategies]); and (c) theory of action (RBA: What do we propose to do? [action plan])

Discussion Questions (part 1/2)

Compare and contrast the approaches used by the Dr. Juan Nieves and the health educator.

1. What are the advantages and disadvantages to each approach?
2. How can they improve their collaborative approach?
3. What causal graph(s) does the epidemiologist have in mind? (extra credit)

Case scenario (continued)

After an extensive vaccine safety campaign you are very surprised to see student vaccination rates *significantly decline* among families with “concerned” parents, yet *moderately increase* among families with “nonconcerned” parents.

Discussion Questions (part 1/2)

Based on the surprising results, answer and discuss the following:

1. What might explain these observations? (think PDSA double-loop learning, including program theory)
2. Propose a new program theory that might explain the surprising results. Start with a root cause model (theory of causation), and then build up. Discuss with your learning partner(s).
3. How will you test your new program theory?

Case scenario (closing thoughts)

Every public health intervention has a program theory, and it should be stated explicitly. When available, adapt evidence-based frameworks for your target population and intervention. For example, Figure 7 depicts a conceptual framework for vaccine hesitancy that may help you design your program theory [18]. Although a framework is not a causal model, it can be a very useful conceptual tool to support your causal thinking and program theory design.

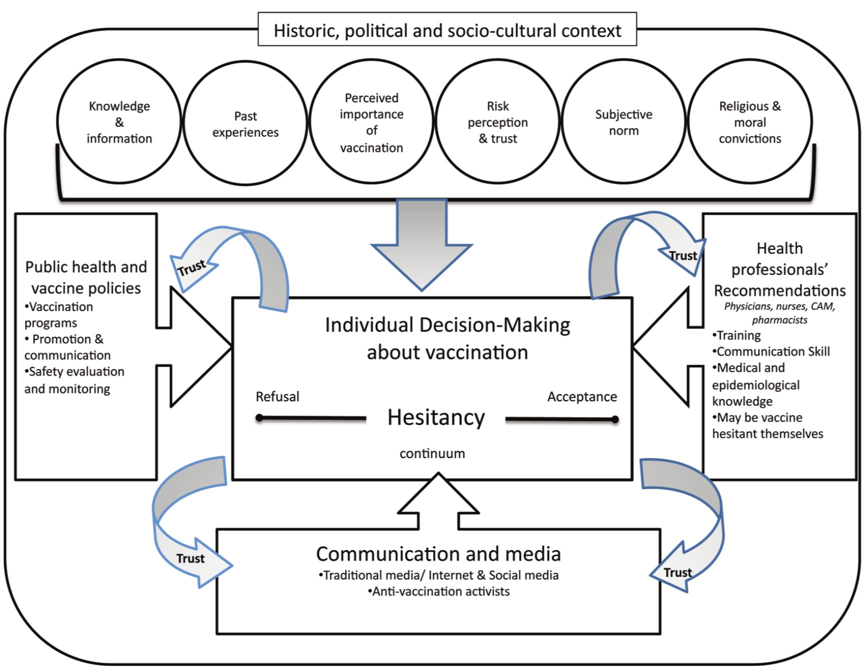

Figure 7. Conceptual model of vaccine hesitancy

APPENDIX

A What are causal graphs?

Causal graphs, also called directed acyclic graphs (DAGs), are used to display causal links. If the value of Y depends, in some way, on the value of X, then $Y = f(X)$, and Figure 8 applies:

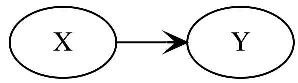

Figure 8. A directed acylic graph.

Directed acyclic graphs have three fundamental forms: chain, fork, and collider (Figure 9). All causal graphs are constructed from chains, forks, and colliders. DAGs cannot cycle ("acyclic"); for example, this form ($X \to Y \to X$) is not permitted.

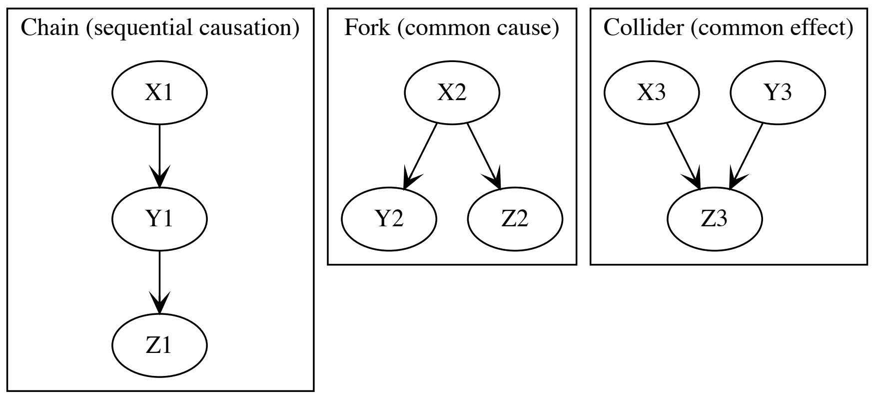

Figure 9. Directed acyclic graphs have three fundamental forms (chain, fork, and collider)

DAGs are very powerful because they can be constructed from expert knowledge, common sense, and/or scientific evidence. It is very important for us to visually display causal pathways so we can discuss and improve our work. Drawing DAGs only requires common sense and subject matter familiarity.

Then epidemiologists can then use DAGs to design analyses, and to test if the causal links are supported by the observed data. To learn more about DAGs for causal inference and statistics study Pearl [19].

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