"When You Assume…"

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This paper shows how to develop better causal loop diagrams by using simple thinking tools borrowed from other fields of endeavor. It will be a valuable starting point for practitioners looking to add a new dimension to their work, as well as for educators wanting to offer a richer learning experience. That is not to say that any of the diagrams found in this paper are works of genius, or even that they are anything more than early drafts - only that the "after" versions are better than the "before" versions, thanks to the use of the tools described here.

I. Introduction

The Causal Loop Diagram (CLD) is a fundamental and extremely powerful tool of systems thinking. Its accessibility makes it ideal for introducing systems thinking to the uninitiated, yet it is robust enough that it can also be an early step in the process of developing a complex model for simulating system dynamics.

There is, however, something that can corrupt the power of CLDs - unexamined assumptions. The examination of assumptions is something that receives little or no mention in the teaching of CLDs, and represents a challenge even for the seasoned practitioner. Especially significant are the *underlying assumptions* of those working to develop the CLD, because they are not simple errors in logic; they are unwitting errors in the input to the logical process. Even when the logic of a CLD is impeccable, invalid assumptions underlying the diagram can render it ineffective or even harmful, leading to disastrous interventions despite the best of intentions. Further, any subsequent simulation model that preserves those assumptions will not reflect reality no matter how precise or exhaustive the model might be.

Fortunately, some simple but potent tools make it possible to surface and challenge critical assumptions underlying a CLD. This paper will describe the tools; present several easily recognizable problems taken from the world around us, expressed in crude, first-draft CLD form; and then apply the tools to illustrate their worthiness as well as the sometimes shocking effect their use can have on the CLD development process.

II. Meet the Tools

A. The Logical Approach

Few students today (in the US, at least) receive training in logic and rhetoric. While this may be considered disastrous for any number of reasons, its relevance to the subject of this paper is that those who have not been schooled in these areas are at a disadvantage when it comes to drawing CLDs.

While it would be inappropriate to attempt to shoehorn an entire course on logic into this paper, for our purposes we must at least review the category of logical fallacies known as "causal fallacies" - since, by definition, every link in a CLD represents, at a minimum, an assumption of causality.

Coincidental Correlation (post hoc ergo propter hoc)

A fallacy committed by assuming that, because event B followed event A (*post hoc*), therefore (*ergo*) B was caused by A (*propter hoc*). (e.g., "Every morning the rooster across the street crows, and immediately after that the sun rises. Therefore, the rooster must be causing the sun to rise by crowing.")

Joint Effect

Sometimes considered a special case of *post hoc ergo propter hoc*. A is held to cause B when in fact both are the effect of a single underlying cause. (e.g., "The lifeguard noticed that, on days when bathers on his stretch of beach bought significantly more ice cream than usual, he had to rescue significantly more swimmers in distress than usual. He concluded that a combination of eating and swimming was unwise, just as his mother had always warned him." The lifeguard neglected to observe that the amount of ice cream consumed and the number of distressed swimmers both went up on days that were significantly hotter than usual - oppressive heat being the underlying cause of both effects.)

Insignificant Cause

A fallacy committed when A, which does indeed contribute to B, is considered before more significant causes. (e.g., "Smoking causes air pollution in New York City." This is true, of course, to a degree - but its effect is insignificant compared to the effect of auto exhaust.)

Wrong Direction

A fallacy committed when the relationship between cause and effect is reversed. (e.g., "If we want our children to receive a good education, we must make sure their grades are high." But high grades are not the *cause* of a good education; rather, they are its *result*.)

Complex Cause

A fallacy committed when A, which does indeed contribute to B, is nevertheless only one of several causes that are all necessary. (e.g., "The fireball that burst from my barbecue happened because I squirted lighter fluid onto it." This statement is partially true, but without the presence of heat from the charcoal and oxygen in the atmosphere, no fireball would have resulted.)

Figure 1: Causal Fallacies

B. In Search of Conflict

The Theory of Constraints, developed by Eli Goldratt, introduces a thinking tool called the Conflict Resolution Diagram (CRD), as shown in Figure 2. The effectiveness of this tool rests on the theory that problems within a system often exist due to powerful forces in conflict with one another, usually due to incompatible underlying assumptions. The tool is designed to surface those conflicts so they can be resolved.

Using the CRD requires serious thought, but the structure of the diagram itself is quite straightforward. In order to achieve some stated objective, we must meet some requirements. In order to meet those requirements, we must meet some prerequisites. Those prerequisites have further prerequisites, and so on. If we continue this thought process, we will often encounter two or more prerequisites that conflict with one another. Assumptions underlying that conflict, once they have been exposed, can be invalidated or broken, leading to a breakthrough.

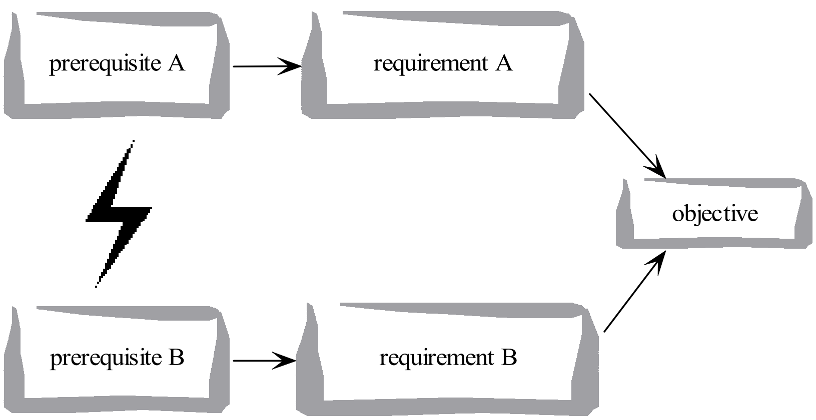

Figure 2: Conflict Resolution Diagram

III. Apply the Tools

A. The Winning Athlete

1. Objective: High Level of Performance

Figure 3 illustrates the dynamics involved in a world-class figure skater's performance, which is dependent on two factors: *focus*, meaning attention to a single task; and *flow*, meaning execution of the task without explicit attention to the individual steps of the task. Self-consciousness and anxiety about making mistakes are detrimental to focus and flow, and are therefore detrimental to performance. Good performance reduces self-consciousness (R1) and anxiety (R2), while at the same time raising expectations (B1). Poor performance, of course, has the opposite effect.

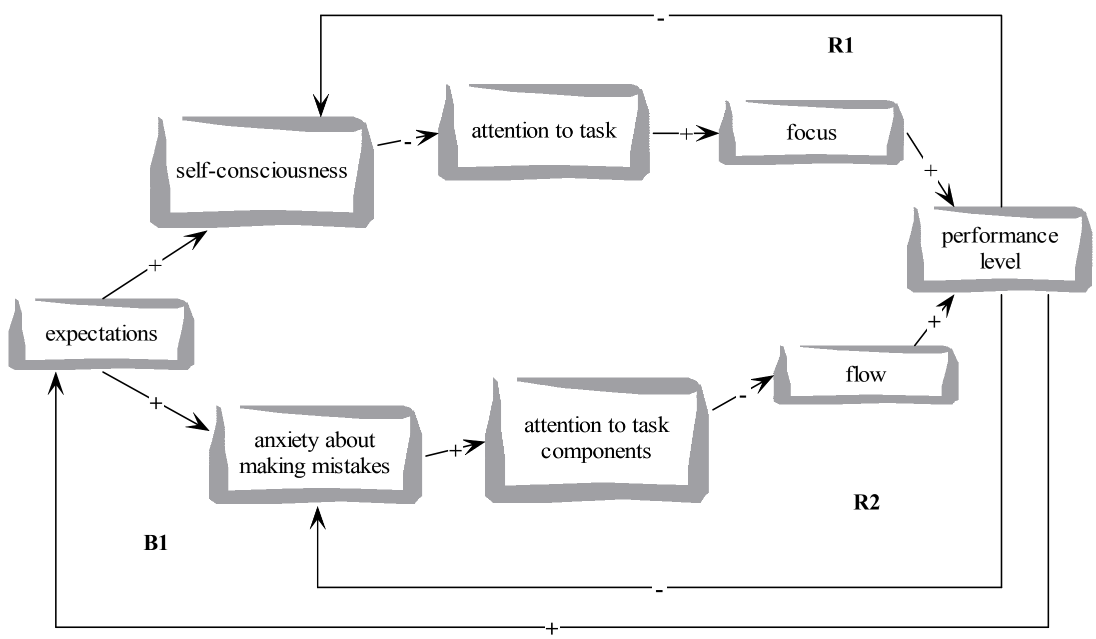

Figure 3: Achieving Focus and Flow

2. Chosen Means

This dynamic is familiar to coaches and sports psychologists, even if causal loop diagrams are not. The most common interventions made on the athlete's behalf take the form of psychological counseling and exercises (relaxation techniques, visualization, positive thinking, etc.) and preparation (practice, conditioning, videotape reviews, etc.).

3. Discussion

While this could hardly be considered the finest CLD ever developed, it nonetheless captures the essence of the situation and is an acceptable first draft. To begin improving it, let's introduce a Conflict Resolution Diagram, as shown in Figure 4. Applied to this particular case, it illustrates that if we trace back from each of the main requirements for high performance (focus and flow) through a chain of prerequisites, we soon find that two of those prerequisites conflict with one another.

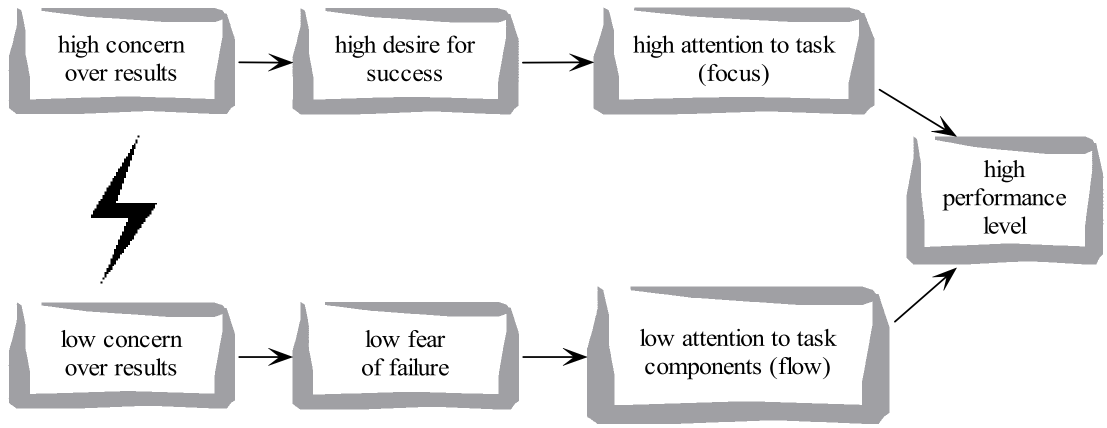

Figure 4: Searching for Conflict is Not the Same as Looking for Trouble

Our awareness of the conflict helps us to see that this example is, at its core, a classic problem of balancing *risk* with *reward*. If the reward is great enough, there will be a high concern over results (equivalent to greater desire for success); and as the risk associated with failure is reduced, there will be less concern over results (equivalent to lower fear of failure). To resolve the conflict we must generate a concern over results that is high enough to challenge and motivate, but low enough to encourage rather than intimidate - which many readers will recognize as a parallel to a well-known strategy for effective goal-setting.

This leads us to the rather basic question of how the skater chooses goals and defines success and failure - two words among several that we have been playing fast and loose with up to this point. For any given competition, if winning that competition is considered the only acceptable definition of "success," then the risk of failing to achieve that goal is extremely high. When skating in exhibition, however, the skater has different goals and defines success and failure quite differently than in competition; and "success" is far more likely, since that term is no longer confined to a single narrowly defined outcome.

This thought process exposes an assumption implicit in our original approach (that "performance," "winning," and "success" are identical) and suggests a slightly different approach. The updated CLD in Figure 5 does not invalidate the interventions mentioned earlier, but it does open the door to another family of interventions. For example, counseling can help the skater recognize that a career as a competitive skater consists of many competitions, and therefore consists of many opportunities to win beyond the current competition. Further, each competition can be assigned one or more of a set of layered goals or objectives - improvement in a particular jump or piece of footwork, increased artistry, greater speed, more endurance, and so on - which will improve the skater's chances to win future events while also increasing the number of successful outcomes available in any single competition as well as in a career of competition.

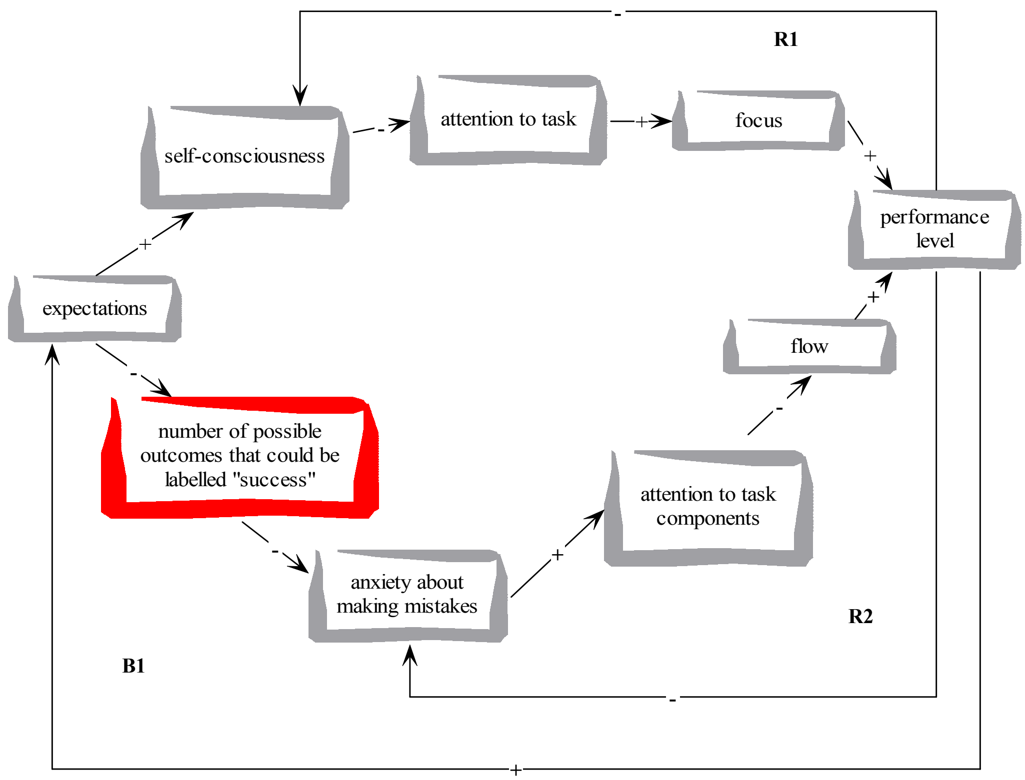

Figure 5: Objectives and Success

B. Holding Our Schools Accountable

1. Objective: High Standardized Test Scores

The standardized test scores of our nation's youth are the subject of much concern - and much legislation. Standardized tests that had been mandatory only every other year between third and eighth grade are now mandatory for every year in that range. Schools are being pressured to increase standardized test scores, and the schools that fail to do so within the next few years are threatened with being restructured (replacing all staff and faculty and revamping the curriculum) or taken over by the state. By applying pressure to the staff and faculty of our schools in the form of deadlines and reverse incentives, we hope to create accountability and ensure that test scores rise.

2. Chosen Means

The dynamic is illustrated in Figure 6. Of course, most parties involved expect children who are well schooled in the fundamentals to perform well on standardized tests (B2). As most parties are also aware, however, the pressure to raise scores has generated some unintended side effects. The pressure is severe enough that teachers begin "teaching to the test" - that is, preparing students specifically for the tests - in hopes of raising the scores high enough and quickly enough (B1). In so doing, they reduce the amount of time spent teaching fundamentals (R1).

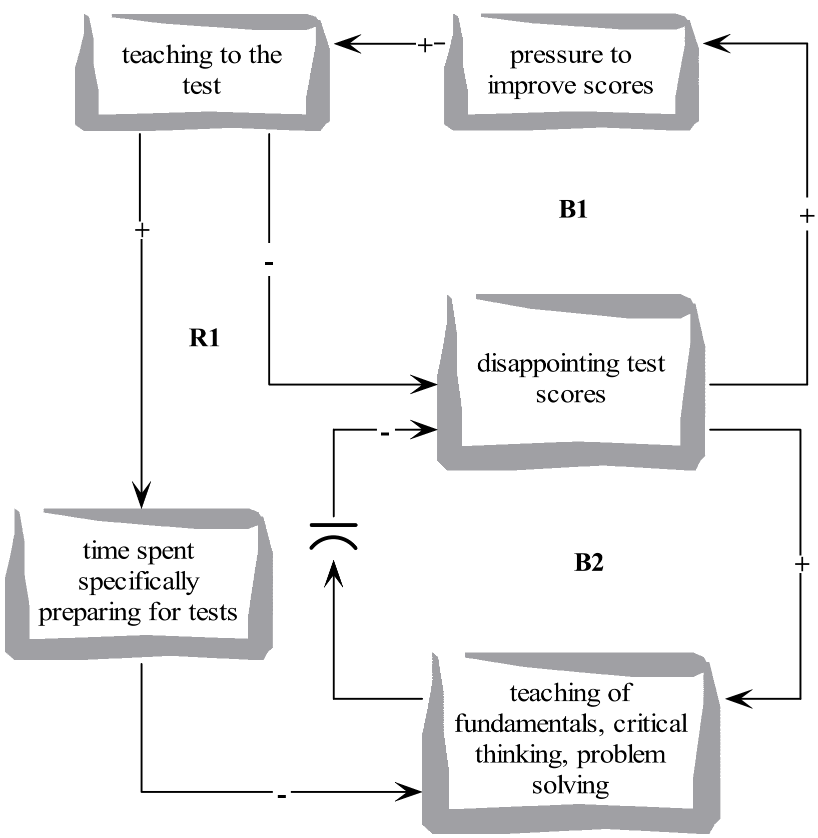

Figure 6: Lighting a Fire

To solve this dilemma, some schools have set aside quotas of time specifically for test preparation, with further reverse incentives designed to prevent teachers from exceeding those quotas. The understanding is that this action will choke off loops B1 and R1, and force more time into the desirable B2 loop - despite the loop's inherent delay and the looming deadlines.

3. Discussion

This dynamic is riddled with unexamined assumptions. Let's discover some of them using a Conflict Resolution Diagram (Figure 7). First, we declare our objective: higher test scores. Given our actions, one can infer that the requirements to achieve this goal are 1) more frequent administration of the tests; and 2) pressure on schools to improve their scores.

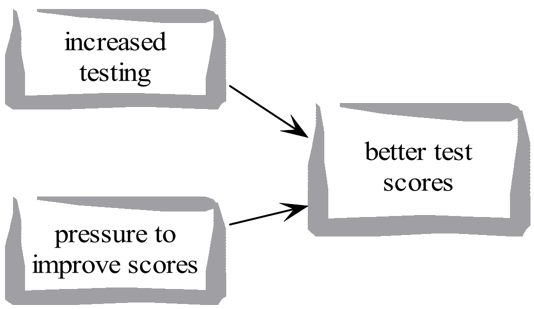

Figure 7: Shooting for Higher Scores

At first it's difficult to see any cause-effect relationship between more frequent testing and improved scores; but proponents of more frequent testing explain that, combined with the pressure on schools to improve scores, it forms the accountability so necessary to bring about improvement. The argument is not that the testing itself causes improvement, but that it provides information for all parties to act upon in their improvement efforts - that is, it helps schools and legislators to evaluate progress and identify which schools are failing and which are succeeding.

Consideration of the link between pressuring schools and better scores exposes one of the critical assumptions underlying the dynamic. Since the pressuring legislation includes no fundamental change in the system or means by which schools educate their charges, one of two things must be assumed to be true of any school identified as a "failing" school: either the faculty and staff could have been doing better all along but chose not to (and therefore need the special motivation that threats will engender); or they are simply not capable of meeting the expectations placed upon it (and therefore needs to be identified as such, for possible elimination). When the stakes are such that the possibility exists of being not only unemployed, but implicitly labeled as lazy and/or incompetent, is it any wonder that teachers might teach to the test that determines their fate, and sometimes even ignore any restrictions on doing so?

This line of reasoning demands that we ask the question: Why don't teachers just do a better job of teaching (the B2 loop) instead of teaching to the test? Given the way we have defined the situation thus far, the answer again can only be one of two possibilities. Either they can't do it, or they haven't been bothering to do it - and are now so far off course that they can't risk getting back onto the B2 loop because they fear the inherent delay of that loop might cause them to miss crucial deadlines.

The reader will recognize how grim this view of the situation is: some (unknown) number of schools is either unable or unwilling to provide an acceptable education to our children; and those schools even attempt to circumvent legislation intended to identify the incompetent and motivate the unwilling, at further cost to our children's education. Fortunately, this assessment rests on flawed assumptions; unfortunately, a more accurate assessment is even more grim.

If we take a moment to step back and consider the problem in a broader context, we can acknowledge easily enough that the reason we want higher scores is that we want our children to receive a better education. We want them to be well schooled in the fundamentals, able to think for themselves, and prepared to deal with the myriad and unpredictable problems they will face throughout their lives. Updating our previous CRD to include "better education" as our higher goal (Figure 8) makes another assumption obvious: the assumption that the types of standardized tests currently in use are appropriate, meaningful, and sufficient measures of educational achievement. A bit of reflection reveals that this assumption is key to the entire dynamic. The test results are the linchpin in the process of evaluating schools and determining the fate of faculty and staff.

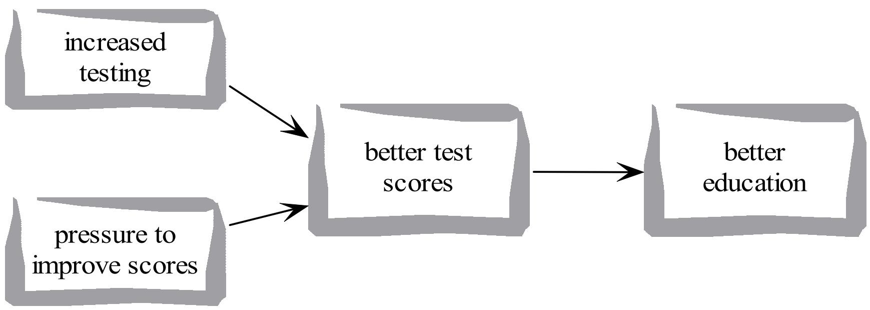

Figure 8: Aiming for a Higher Purpose

Consider the ramifications if the assumption were false, and the tests did not provide a useful measure of the education being provided by the schools. The entire dynamic would crumble. All improvement efforts that targeted the test scores would be seen as misguided. The labeling of hundreds of schools as failures, and the termination and attendant stigmatization of thousands of staff and faculty, would turn out to have been entirely unjustified, even libelous. Imagine the destructive and demoralizing effects we would have visited upon an entire class of professionals dedicated to the development of our youth.

A full determination of whether or not this assumption is flawed should be deferred to a separate forum. Obviously, many believe that the tests accurately and reliably measure the quality of education - at the same time, paradoxically, believing that the tests can be fooled by "teaching to the test." The reader is invited to reflect on what compelling evidence exists for each side of the argument, keeping in mind the stakes involved.

If we decide to accept the assumption that the tests are a useful measure of education, we nevertheless still can see that the new connection in the CRD is a causal fallacy ("Wrong Direction"). Good test scores do not lead to a good education; rather, a good education leads to good test scores.

Let's start over with a new CLD (Figure 9) that now explicitly includes the objective of a quality education, with the relationship between education and testing the right way around. Perhaps the most striking effect of doing so is the way it focuses the CLD on process rather than results. Instead of the pressure being on schools to produce better test scores, the pressure is on them to do the things that ensure students receive a quality education. It follows that students should then score better on any tests that measure education effectively.

The conclusions we may derive from this CLD are significantly different from our earlier conclusions. Our previous diagram reflects the dynamic currently at work; our new one suggests an entirely different - and more logically sound - approach. While testing remains useful (assuming the tests are a good measure of education), there must be strong interventions focused on measuring and improving the education process itself, not just on its results. This will require of our leaders a great deal more work and a far deeper (and earlier) commitment than is required to simply review test scores after the fact and point fingers of blame or hand out awards. To use an automotive analogy: if we wish to travel the road of improving education for every child, then looking at even meaningful test scores is like looking in the rear-view mirror at the road behind us - a very small part of the process which, though advisable from time to time, gives no indication of what lies ahead and makes no contribution to forward progress.

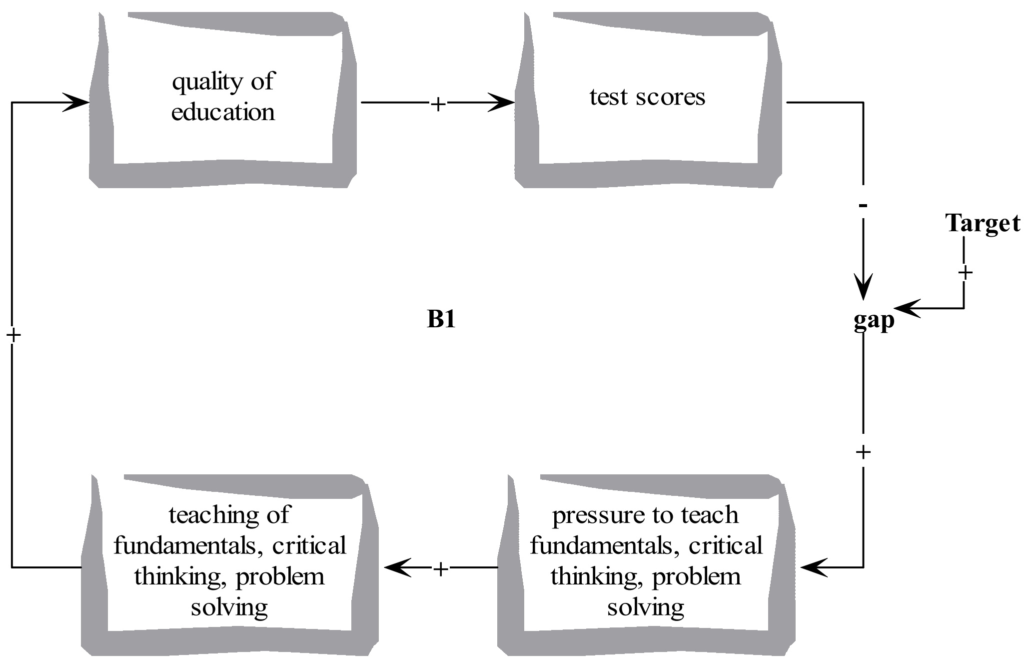

Figure 9: The Quality of Education Is Not Strained

C. Reducing Industrial Accidents

1. Objective: Low Injury Rate

In any industrial setting, injuries caused by accidents are a serious source of concern. Their rates are tracked, plotted, and pored over by supervisors, union leaders, regulatory agencies, and countless others in offices everywhere, from the smallest factories to the largest industrial giants. Reducing the injury rate, or keeping it low, is not just a humanitarian issue. It makes good business and financial sense as well; insurance is cheaper, medical and leave expenses are lower, and people feel better about working in a place they feel is safe.

2. Chosen Means

Perhaps the most well-known and often-practiced method of reducing injuries resulting from industrial accidents is the use of safety incentive programs, the logic of which is illustrated in Figure 10. Given a (presumably low) target for the number of injuries, incentive programs are put in place to ensure that workers are properly informed and sufficiently motivated to behave safely. Safe behavior reduces the number of injuries, shrinking the gap between the number of injuries and the target.

Traditional safety incentive programs usually take one or both of the following forms:

- Performance incentives: rewards or prizes are given out, contingent on achieving or maintaining some predetermined injury rate over some predetermined time period
- Participation incentives: rewards or prizes are given out, contingent on attending safety awareness meetings, participating in safety-related activities, or successfully completing safety training programs

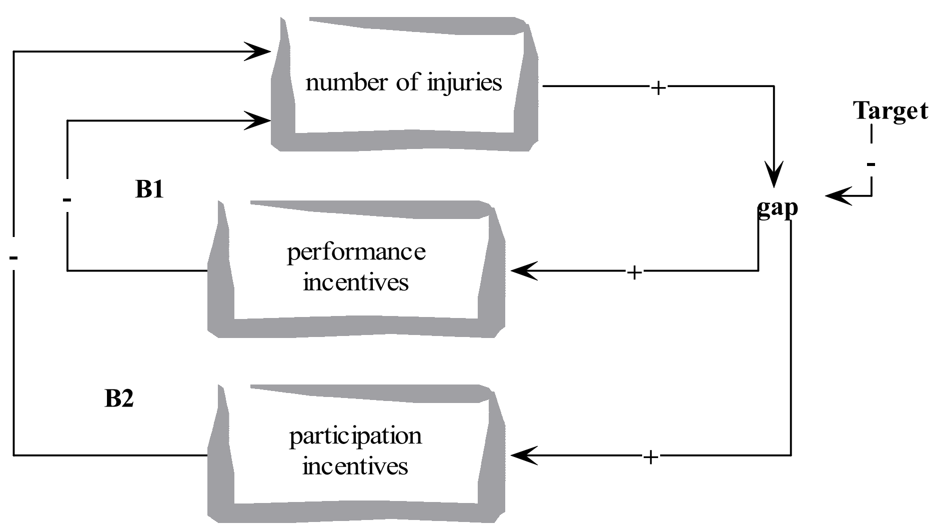

Figure 10: Avoiding the Dagger in the Floor

3. Discussion

It would appear that nothing could be more simple, elegant, or guaranteed of success than this approach. Unfortunately, the key links between incentive programs and number of injuries suffer from the causal fallacy of "Complex Cause."

Accident and injury rates are a function of risk, which can be avoided, but which also can be reduced. Imagine a large dagger, its handle stuck in a factory floor and its blade pointing upward. Workers in the factory can be warned of its presence and trained to avoid stepping on, stumbling over, or falling onto it, and they can be rewarded for every month in which they have avoided injury from it. Then again, it could simply be removed from the floor, removing the associated risk along with it. In such a case, one might argue that the fallacy at work in Figure 10 is not "Complex Cause," but "Insignificant Cause." Removing the dagger from the floor is a far more powerful intervention than endless rounds of meetings, training, and awards programs.

Risk derives from multiple sources. First, workers might be unaware of safety hazards; second, they might not know how to avoid or reduce them; third, they might not choose to avoid or reduce them; fourth, the facilities and equipment might create risk; and fifth, some features of the work environment might be counter-productive to the avoidance or reduction of risk. Traditional safety incentive programs deal only with the first three sources (and only the avoidance components of those), and not at all with the last two sources. Let's consider the impact of such a strategy.

As seen in our previous example, imposing performance incentives based on results focuses attention, as one might expect, on those results rather than on the process itself. Under the circumstances, since the workers themselves are powerless to "remove the dagger," such incentives encourage under-reporting of injuries (Figure 11) - actually *contributing to* the fifth source of risk noted above. Some workers may even suspect that the company is trying to "buy off" injuries to achieve lower (false) numbers. Further, these incentives send the demoralizing message that the company believes the workers are foolish enough not to take heed of their own safety unless there are trinkets to be had for doing so. Even worse, the company makes that belief self-fulfilling and self-propagating by creating an addictive sense of entitlement - "If you give me extra rewards just for not hurting myself, what extra reward will you give me for doing my job and helping this company make money?"

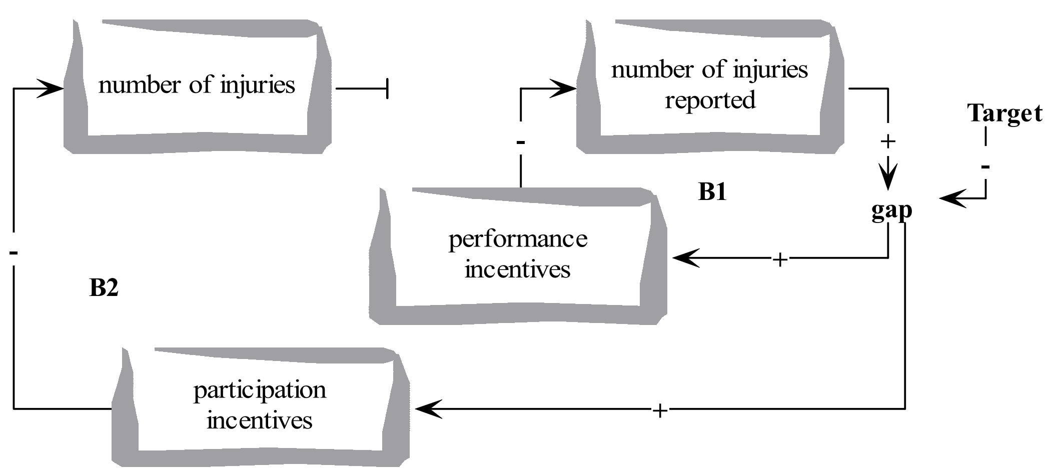

Figure 11: Safety Short-Circuited

In summary, such incentives demoralize the workforce, foster a sense of entitlement, distract workers from even thinking about possible process improvements, and encourage the falsification of vital injury data (all extremely negative consequences, extending beyond safety issues into areas such as productivity, morale, retention, compensation, and trust). Yet they remain popular, even despite the lack of any clear causal link between them and real injury rates.

Training in safe behaviors can be valuable, as can safety audits, and meetings to raise awareness of safety issues; and if workers are concerned for their own safety they certainly will want to participate in any activity that can help them behave safely. Additional incentives to participate should be unnecessary. If they are, it should be clear that the workers do not find the activities effective - and where there is no clear connection between the activity and an increased sense of safety, the focus shifts once again to the rewards for participation and away from the substance and content of the activity.

We have identified a causal fallacy in our original CLD - a fallacy that led to some sources of risk being ignored - and we have also uncovered a familiar (by now) assumption that the workers will not do what it takes to behave safely unless they are bribed (or threatened) into it. If we deny that assumption and correct the causal fallacy, our next version of the CLD will look quite different than it did before - perhaps something like Figure 12.

No one knows any better than the workers themselves where the "daggers" are in their workspace. When they are engaged in identifying risk and in sharing meaningful knowledge of risks with one another, and when they are given the authority to change facilities, equipment, and their environment (physical and policy-related) to reduce risk and make remaining risks more avoidable, real injury rates will decrease. It's not unreasonable to conclude that morale, trust, and worker dedication might improve as well, not to mention productivity and pride of workmanship. Of course, there wouldn't be quite so many trinkets gathering dust on shelves in workers' homes; but perhaps that is the price one must pay for a safer workplace.

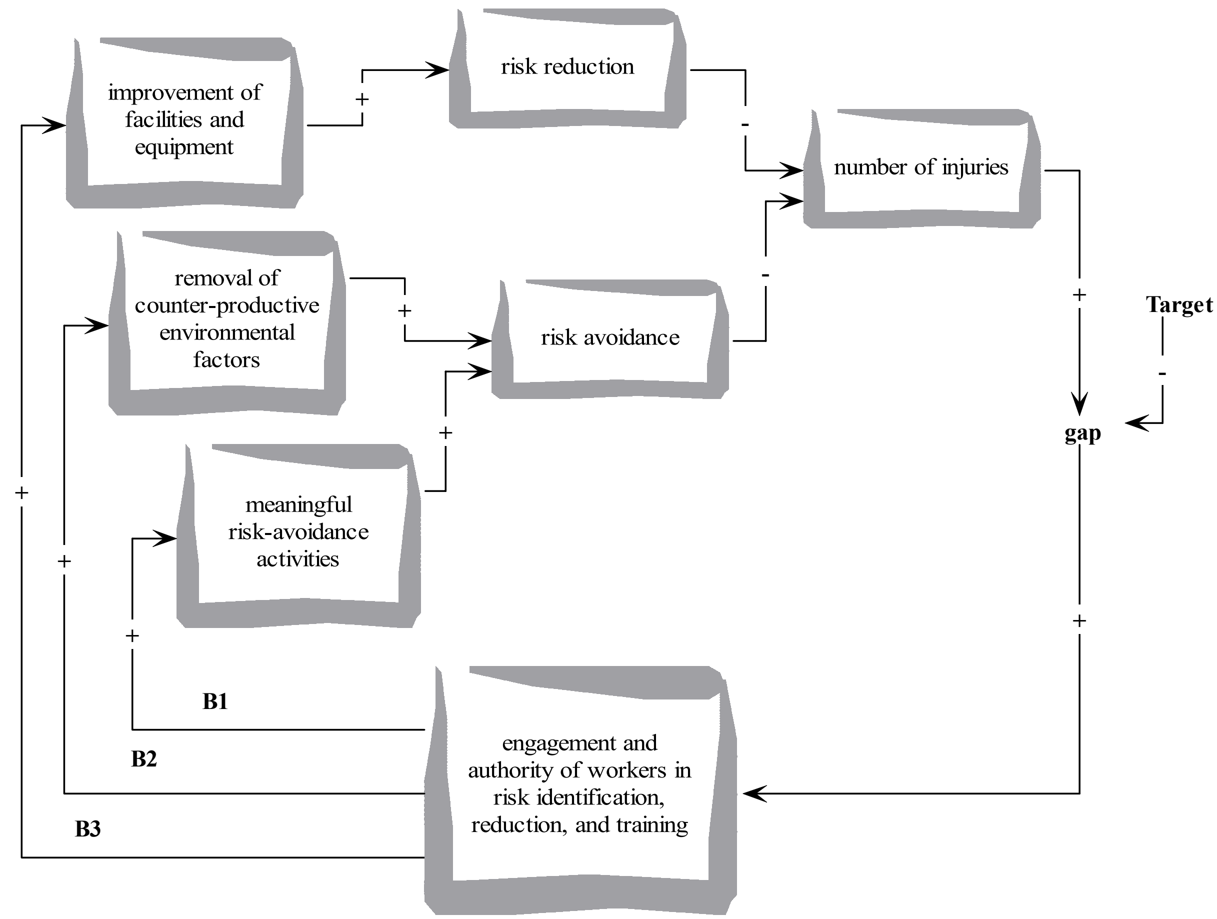

Figure 12: Building a Culture of Safety

IV. Conclusion

There is much more that could be said about the diagrams discussed in this paper. No doubt, in the course of our discussion there have been logical fallacies committed and critical assumptions overlooked. Further effort will bring further revelations, and will require further revisions. The "final" versions, if they may be called that, perhaps will bear only a passing resemblance to the diagrams found here. It is certain, though, that they will be nothing at all like the earlier versions described here, since the flaws in those earlier versions have been exposed.

The tools discussed in this paper do not eliminate the need for creativity or insightfulness; those traits are still required among CLD developers. They are, however, useful weapons in a developer's arsenal. They help developers by improving the process of developing CLDs; they enable developers to think about problems in a more deliberate way; they contribute to making underlying assumptions explicit; and they help to bring the powerful promise of CLDs to fruition.

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