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Chapter 6

Systems Thinking and Learning with the Systems Intelligence Perspective

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This article delves into the systemic dimensions of learning, particularly in the sense of non-conceptual, intuitive learning. Even though complex situations and problems may be beyond our ability to reason, we as human beings still possess intuitive tools for solving problems and learning from and of our environment. These tools, while present in every human being, are not necessarily being used to their fullest potential. Combining them with simulative learning environments may open up new vistas for learning, both for the individual and for groups.

Introduction

Even though the surrounding world continues to dazzle us with its complexity and ever-evolving nature, we still somehow manage to hang on. Much of our learning happens at a non-conceptual level and we realize a lot more of the underlying causal relations than would at first glance seem to be possible. Inbuilt mechanisms drive our learning and understanding, and because of that, we act intelligently even when no apparent framework to leverage with reason is available.

The question then is whether or not we should be more aware of these mechanisms and ways we can take advantage of them to further our understanding of the world and of ourselves. And if the answer is yes, how can such awareness arise other than through sheer life experience? This paper argues that simulations may prove to be useful for enhanced understanding of the world we live in and the systems we interact with.

Systems Thinking as a Tool for Understanding the World

John D. Sterman is a leading advocate and a pioneer in the movement that is called systems dynamics. His book *Business Dynamics* (Sterman 2000) is a comprehensive work that, for many people, is bound to help them understand how complex systems work. In the book and in his article, *Learning in and about complex systems*, Sterman argues that the human capacity to understand complex systems is woefully inadequate, and much practice is needed to properly understand the various causal relationships between variables. For example, if presented with a simple causal relationship, such as the inflow to and outflow from a bathtub, most people are unable to infer correctly the behavior of the amount of water in the tub. Even when presented with a simplified explanation of the system, it still is not readily apparent how the system will behave. The problem is even more evident with real-world systems of complexity, in which it is difficult to comprehend the causal relationships or to be able to predict the system's behavior intuitively.

Sterman presents more detailed examples in the book. Car manufacturers in the USA used to offer very short term lease plans for their cars, reckoning that it would boost their sales as new cars would be perceived by customers as easier and less risky to acquire. What they did not take into account was the fact that after a certain delay, the used car market would be flooded with these almost-new vehicles and thus, even less people would hold on to their car after the lease period expired (lowering used car prices and thus creating a positive feedback loop in which even more people would off-lease their vehicle) and even more damagingly to the car companies, cheap, good-condition used cars heavily undercut the sales of new cars, hitting the companies' profits hard. This is an example of a seemingly rational move (boosting car sales in the short term) that, due to the nature of the whole system which in the initial decision-making went unnoticed, ends up achieving just the opposite of what was desired, in this case, lowering new car sales substantially.

These examples demonstrate how oblivious we can be to the systems around us. What's even more, even if we are presented with explanations of these systems, such as causal charts, sets of equations etc. we still cannot bring ourselves to comprehend the true inner workings of the systems. As Sterman points out, we often act in an event-based manner, disregarding any possible delays. Most of the things we are adept at, such as riding a bicycle, offer instantaneous feedback of our performance and allow us to quickly change our behavior accordingly. Our brains are hardwired to learn quickly in a situation like that, and a task like riding a bicycle which would seem insurmountable given all the equations of friction, gravity, velocity and inertia that are the mathematical representation of it, is entirely doable with a little practice. Unfortunately, as delays between action and result, cause and effect are introduced, our inbuilt learning mechanisms have a much harder time of coping with them. Systems thinking is a movement that seeks to help people develop mental tools to comprehend these complex networks of intertwined causes and effects.

The Mental Framework

Systems thinking, as a discipline, recognizes the importance of mental models. Mental models are, in the words of a leading systems thinking advocate, Barry Richmond, "selective abstractions of reality that you carry around in your head." (Richmond 1997). The whole concept of a mental model revolves around explicit knowledge: "If you wish to employ non-rational means (like gut feel and intuition) in order to arrive at a conclusion or a decision, no mental model is needed. But, if you want to think… you can't do so without a mental model." (Richmond 1997) Mental models are constructs that are semi-reachable from consciousness in the sense that we are aware of them (at least once we've been given the idea of a mental model), but are tacit in the sense that they are not easily explicated as discussed by Sterman in "Expert knowledge elicitation to improve formal and mental models" (Sterman 1998).

Mental models are also featured prominently in the visual description of the learning process that Sterman provides in his paper "Learning in and about complex systems"; this diagram is reproduced in Figure 1.

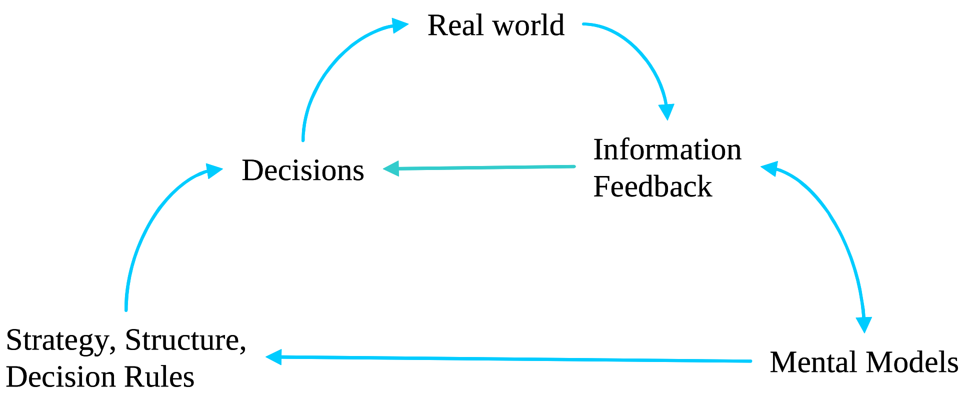

Figure 1. The learning process (Sterman 2000b)

The figure unfolds as follows. We make observations of the real world and based on those, we make decisions which in turn influence the world. This is what could be called the main loop in the chart. However, we base our actions on previous interactions with the world. These are represented in the mental models, which are our inner models of the outside world based on all previous interactions. Based on these mental models, we formulate strategies and heuristics for dealing with the real world, which in turn guide our decisions. It is important to note that the interaction between the feedback we get from the world and our mental models is two-way; new information shapes our mental models but in turn we view feedback from the world through the glasses of our existing mental models. Mental models are important to how we interact with the world. Sterman puts it thus: "on the contrary, our world is actively constructed – modeled – by our sensory and cognitive structures." (Sterman 2000b) Thus we can expect that more refined mental models result in more accurate actions, resulting in a better input/output relationship between perceptions and actions. On the other hand, even a small distortion in the mental models can change the way we perceive a phenomenon, and because it can further reinforce itself in the loop, the bias may end up as a dominant factor for the phenomenon in question. Thus even small biases can distort the mental models severely, if they are based on a narrow experience base.

If learning involves evolution of the mental models, which are the cornerstone of our conceptual understanding of the world, certain requirements for effective learning can be identified on the basis of Sterman's learning process. First of all, a large exposure to new things is necessary to form a proper mental model about them. A narrow base of experience will lead to biased views of the phenomenon in question. A major issue to consider here is the human incapability to see the stochastic nature of the world we live in, that things that work one time might not the next time, since other relevant parameters will have changed, even if the agent's actions are precisely the same. We will return to this issue later on when discussing simulation as a way to gather experience about unfamiliar situations and environments, and the effects of our actions on them.

Secondly, it is necessary to get accurate feedback in order to learn properly. If feedback is incomplete, distorted or delayed, learning is severely impaired. Like previously mentioned, the human mind is not by default conditioned to cope with noisy and delayed feedback, though the capability can be improved. A classic example of this is the Simple Beer Distribution Game (for a detailed description, see Sterman 1992), where a very simple system goes out of control simply because the players do not take deterministic delays into account while playing. Simulation can help in this as well.

The third requirement is that a person needs to have an open mind and be able to re-evaluate the existing mental models, without starting a trench war against new ideas. This might in some sense be the area in which systems intelligence can make the largest contribution. Re-examination of current mental models can be hard, but questioning them is vital to learning. This also involves contextuality of the lessons learned, because learning in one environment can also yield valuable lessons regarding other types of situations.

If all of these three criteria are met, false, biased or incomplete mental models will be exposed and corrected efficiently, and the learning process can work in a more optimal manner. However, not all learning rests on explicit mental models.

Systems Intelligence and Non-Conceptuality

If we consider the fact that it is unadvantageous or even impossible to present all information explicitly, shouldn't we also take this into account when considering learning? Objectivization of knowledge and striving towards more explicit information is a valuable tool for codifying information, but a large part of learning happens at a non-conceptual, non-representative manner. Like Hämäläinen and Saarinen (2008) put it, "those that are 'teaching' might not even know what they are teaching, nor might they be able to point to any objectively identifiable representations of the systems structures they in fact employ, and still people learn, via a kind of 'making a lot out of a little' systems capability that Bruner identifies in children." This stands in stark contrast with Richmond's claim that "…unless a mental model changes, learning does not occur!" (Richmond 1997). If mental models are explicit, and no learning occurs without them changing, does this mean no implicit learning can occur?

Hubert Dreyfus addressed implicit knowledge in his presidential address (Dreyfus 2005) *Overcoming the Myth of the Mental: How Philosophers Can Profit from the Phenomenology of Everyday Expertise*. In the address, he takes expertise into focus and argues that through practice, a tacit form of learning occurs which eventually causes the learner to become more than competent in a given skill, and becomes an expert. However, an expert is unable to explain why he decides to act in a particular way. As Dreyfus puts it, "…the master may make moves that are entirely intuitive and contrary to any preconceived plan. In such instances, when asked why he did what he did, he may be at a loss to reconstruct a reasoned account of his actions because there is none."

Dreyfus puts forward an example in the form of lightning chess. This type of chess game involves the players making their moves very quickly (in less than a second per move), so that the whole game lasts less than two minutes. Yet, these games, when played by chess Grandmasters, are as complex as normal Master level games. Dreyfus notes, "At this speed he (the Grandmaster) must depend entirely on perception and not at all on analysis and comparison of alternatives.” The Grandmaster doesn’t think his moves, but rather just simply reacts to the patterns on the board. In this sense, a task as complex as playing chess can be non-conceptual. What the chess grandmaster has developed is not a complete mental model of the game, but rather a “feeling of a system” (Hämäläinen and Saarinen 2008), in this case, the feeling of the system of chess.

Another relevant example could be jazz improvisation. A jazz musician accumulates the skills needed to jam with a band during his whole playing career, and the patterns the band weaves through playing together can be complex indeed, even though there is no central guiding rules except for a few, such as the scale etc. However, the musician would be, just like the chess master, at a loss to explain why certain passages need to follow others in the song; he just knows it. Moreover, unlike in chess, where a supercomputer could find the rationale behind some move, in jazz improvisation no formal explanation can be constructed algorithmically. It’s not just that the associated decision-making is non-conceptual but the whole process is non-conceptual. This is what Hämäläinen and Saarinen (2006) talk about when they say “…human activities that worked, even when there was no theory to explain why they worked, or even a recognized need for a theory.”

To help comparison between the more conceptual mental models and the non-conceptual, implicit knowledge, let us call the latter “tacit models”. An example of a tacit model would be the model which guides bicycle riding, or guitar playing. While obvious that there is some mental construct at work in these activities, the concept of a mental model does not fit the bill very well. First, it is almost impossible to articulate anything about the nature of tacit models, and second, they can only be acquired through personal experience. Tacit models are a sort of “feeling of a system”.

To illuminate the concept of tacit models further, let us take an example of a case in which a tacit model is not strictly rational, yet effective none the less. Sterman argues in his book that model boundaries must be carefully considered so as to include all phenomena which have two-way causalities with the phenomenon to be studied, and that in constructing models it is necessary to “challenge the clouds”. In *Learning in and about complex systems* Sterman recounts a story of a baseball batting champion, Wade Boggs, who always ate chicken before a game after performing particularly well after a chicken meal. As Sterman argues, of course eating chicken in itself did not further the batter’s skills. But here we need to bring Sterman’s own points to bear on himself and “challenge a cloud” by asking whether or not the mental state and constructs of the batsman can be left out from his system of batting? Even though in “the scientific worldview” there is no causal relationship between eating chicken and batting well, if eating chicken serves as a lucky charm which makes the batter believe in himself (even if this is completely irrational) and thus makes him perform better, shouldn’t we view eating chicken a completely rational choice – indeed, the *right* choice?

Surely the system that determines a person’s batting prowess incorporates both physical and mental elements, and neither should be neglected. Of course, attuning one self to batting by eating chicken can be seen as superstitious, but it if works and enables the batter to perform well, it doesn’t seem prudent, wise or productive to judge such a form of objectively ill-founded action too harshly. Of course, if the batter was able to see this superstition for what it is, and be able to attune himself to the games in some other, nonritualistic way, so much the better, but that does not diminish the fact that for him, eating chicken is a sort of system intervention with positive results.

Bearing Dreyfus' earlier points in mind we can take another perspective at Boggs. Boggs, as an expert batsman, would equally be at a loss as the chess grandmaster playing lightning chess to explain how he accomplishes such great results. He might emphasize things like striking posture, swing technique, and eating lemon chicken. The first two are things that many people could agree on, but the problematic third one is no less important, but a part of his tacit model nevertheless. It just happens to be a part of the way he plays baseball. Dreyfus writes, "…expert coping needn't even be even implicitly rational in the sense of being responsive to reasons that have become habitual but could be reconstructed." And as we have concluded, the preparative chicken dinner is not objectively rational, but as a part of Boggs' tacit model of batting, it is an important primer to great performance.

Flight Simulators

If mental models and tacit models coexist in our coping, do they both stem from the same sources? Sterman argues that simulations should be utilized more in making the behavior of complex systems more understandable to us. He has developed what he calls management flight simulators, which are, in his words, "virtual worlds" in which people can interact with the model, much like they would interact in the real world, but see the results of their actions much more clearly than would be possible in real life. For example the confusing effect of delays can be made transparent via simulation, and the oft-misleading stochastics can be made explicit.

Having just recently taken part in a business simulation game, I can wholeheartedly agree with Sterman on their effectiveness in developing an eye for the behavior of complex systems. A business environment, even a simplified one in a business flight simulator, is an immensely complex network of causes and effects that no one person can hope to be able to grasp in its entirety. That is why we observe and control the world at a higher level of roughness, where we see and set trends rather than individual transactions. Most business models are probabilistic in their assumptions and operation, which is a common feature of models in which it is no longer feasible to model lower, more tangible levels (like for example economics abstracts individual consumer preferences away). The trick lies in being able to interpret the interactions of these trends and applying the right leverage in the right point to push the system towards a more favorable state.

Simulations grant us a view to the parameters of the simulation and the effects of our actions that would not be possible in the real world

Using simulations grants us a view to the parameters of the simulation and the effects of our actions that would not be possible in the real world. Simulation allows us to peel away inessential and confusing facets of the system to reveal its core; the core we seek to understand. Things such as delays and unobservable states often confuse us in the real world, where it seems that some causalities that ought to work to our advantage fail to do so while others go unseen and work against us. While this problem is unassailable in the real world, if the models used in simulations fit their purpose well, they are analogous enough that we may gleam understanding from experience in them. The effect of various parameters can be made even more understandable if we allow game participants to vary them and see how it affects the game world. As Sterman (1992) himself puts it, “thus to be effective, management flight simulators must be more than just business games. They must be embedded in a learning environment that encourages reflection on the perceptions, attributions, and other mental models we use to interpret experience as well as the substantive lessons of the situation.” The idea in a simulator is not just to simulate the situation, but to expose the situation and the factors driving it to us. This supports our natural learning abilities and reduces the confusing effects of delays and hidden variables.

According to Richmond, the way simulations affect learning is basically about molding mental models: “call it self-reflective learning. It comes about when simulation outcomes are used to drive a process in which a mental model’s content, and/or representation of content, is changed.” In essence Richmond’s view purports that the virtue of simulations is that they change the content of our mental models. As discussed before, this is a valid perspective, but also lacking. Simulations can also build non-conceptual capabilities. A good example would be learning to fly, not a business organization, but an airplane. Flying an airplane is largely non-conceptual, as evident in the fact that no human could hope to constantly simulate the physical forces actually keeping the plane in the air. The cockpits of flight simulators are designed to resemble the cockpit of the real plane as closely as possible, to make the simulation as close to the real thing as possible. Even the surface materials are chosen to be the same, in order to enable the pilots to develop a tacit model for flying, a feel of the system of flying if you will.

Another advantage of simulations is that they may be used to experience things that are hard, costly or even impossible to do in the real world. For example, it is not possible for the author to spend a few years as CEO of a large company in order to gain business experience and to complete a course for his degree. It’s even less possible when we consider how many peers of his would need to be able to do same. However, using a business simulator, not only is it possible, but rationally thinking even necessary! Simulations enable us to experience things that normally would not be possible, whether is the viewpoint, the situation or our response strategy we wish to try out. And we can go through a variety of runs in a short period of time to develop an intuitive feel for the system, whereas in real life we can only try one course of action in any given situation. To sum it up, simulations open up new situations for us to learn in. As Sterman put it, “most important, when experimentation in the real system is infeasible, simulation becomes the main, and perhaps the only, way learners can discover for themselves how complex systems work.”

Towards a Broader View of Learning in Simulation

Simulation should not be viewed in the narrow sense of computer-based or otherwise external simulations, they may be an integral part of our inbuilt learning drive. This observation legitimizes the use of simulations in learning even further and may give us intuitive insights to its use. There are some additional viewpoints that can shed further light on simulations.

First, simulations can be seen in everyday life as an instrument of learning. Seeing simulation-based learning in other situations than just the pre-designed runs and games that jump to mind can open up new intuitions to their importance to us. Second, simulation are not just a tool for a single person to learn about things, an important part of action is those that act alongside us and thus it's important to remember the social aspects of learning in simulations. This also ties in with the idea that externalizing oneself from the simulation may not be a good idea in the long run. And for simulations to be effective, the lessons learned in them must be carried on to other situations which are not simulations, in other words, new contexts. Unfortunately, this may not be automatic. Finally, no matter what sort of simulation is in question or what lessons there are to be learned, if the actor in the simulation is not open to the lessons, the simulation is useless. In the next five paragraphs, I will explore these topics.

Simulation in Everyday Life

When a layman hears the word simulation, she often thinks of the weather forecast and of some near-mythical supercomputer that makes said forecast. Or animations of wind tunnel simulations in designing new cars, etc. On the other hand, when people with technical backgrounds hear the word simulation, things that spring to their minds are models, runs, variables and statistics. What we need in our discussion, however, is a slightly broadened view on simulation which doesn't necessarily exclude the previous two viewpoints but rather builds on them.

As reasonable as the thought of using simulations to pierce the veil laid upon complex systems is, it would be arrogant to think that it is a purely human invention; nature does it too. Not in the sense of running simulations to predict the outcome, but in learning. As Martin and Caro discussed (Martin and Caro 1985) "… have distilled the many hypotheses into three main classes: play as motor training, play as socialization, and play as cognitive or sensorimotor training. All have in common the notion that, as a result of playing when young, the individual is better able to perform some form of serious behavior later in ontogeny." Animals play in adolescence to build skills. Take for example the play of bear cubs. Considering the argument that Martin and Caro rise, what superficially seems to be just passing time and having fun while growing up is in fact a combat simulation which prepares the adolescent bears for their future lives in which their mother no longer competes for the scarce resources of the wild forest for them, but they are left to fend for themselves. Being able to simulate a hostile encounter with another bear in a friendly environment is valuable training for the life ahead; a life when a real fight against a rival may well decide whether or not the bear gets to make cubs of its own. This fact provides the necessary evolutionary link which demonstrates why playing, which is very common amongst young mammals, has evolved. Martin and Caro express this as "biologists generally assume that for a behavior pattern to have evolved and be maintained by natural selection, it must have biological benefits which, on average, outweigh its costs." So animals simulate to survive and the ability to play is in fact an evolutionary advantage.

Of course, since animals lack the self-regulation and self-reflection capabilities of us humans, it might seem a bit off the point to discuss their simulative habits of learning. This is not so, however; we humans do it too. One might argue that little boys fighting and wrestling is essentially the same behavior we see in the bear cubs, but it doesn't stop there. Learning by playing is an innate inclination in human children, as well. Combining this with the previous discussion about non-conceptual learning (which, considering animals, seems all the more natural now) it seems that simulations could be a major part of our lives already, even if it is not readily apparent at first glance. Of particular note is the fact that play most often develops skills that are not conceptual in nature, and as such might be seen as tacit models. Simulations are thus not something that must be artificially constructed, but something that are a part of our nature and nature at large.

Virtual Worlds and Team Learning

Simulations are not just for individual learning, however. Just as they allow individuals to test their understanding of complexity, groups can also benefit from interaction with the simulation to practice their own interactions. Peter Senge (1990) argues that high-performing teams need "practice fields" in order to further their collective learning skills. Virtual worlds provide a playground for people to experiment in and to build team learning skills. As Senge points out (The Fifth Discipline, pg. 241), "Interestingly, the few examples in business of teams which learn consistently over a long period of time seem to be exactly those settings where effective virtual worlds operate." Based on Senge's observations, it seems that simulations can serve as an efficient facilitator of learning to work as a team.

Human interaction and interpersonal chemistry are largely non-conceptual, so that viewing a team learning simulation solely through the glasses of systems thinking may hide some important notions about the large spectrum of learning opportunities present in a simulation. Formal structure in human interactions, no matter how well conceived, guarantees no results. Much of the interactions arise non-conceptually and the attunement of people to the situation and to each other contributes much to the effectiveness of the group. Interpersonal skills are a valuable inbuilt asset in ourselves which can be bolstered by simulations.

Intersystem Insights

An interesting and familiar phenomenon is that when a close friend is distressed, it's sometimes easy to see her situation more clearly than she herself does. Her judgment of the situation and the causes and effects related to it may be clouded for a variety of reasons, as people are prone to having biases which affect their evaluation of themselves. A person who has intimate knowledge of the situation but does not suffer from these biases is much more able to make a clear assessment of the situation. This is what might be called "the outsider view". An actor which is not in the center of the system in question can perceive the whole much better than one that is in the midst of all the action, as she does not have the biases which affect the central actor. Close participation in a system inevitably brings the biases into play, as the actor needs not only consider the system outside herself, but the two-way interaction between the system and herself as well.

Conceptual learning, as previously outlined, can be seen as the adaptation of our mental models to match the real world as closely as possible. These biases, then, distort our perception of the world and our interactions with it and other actors, and thus result in malformed mental models which do not accurately portray the world. It can be hard to see through the biases, since they alter our perceptions in fundamental ways. The Systems Thinker seeks to externalize the problem field and causal relations in order to study them. As Hämäläinen and Saarinen summarize it, “Systems thinking highlights a domain of objects it believes is neglected – systems. But systems remain objects nonetheless, entities to be identified and reflected from the outside.” Being able to distance oneself from a system is an advantage of simulation with regard to the notion that externalization is necessary for an objective study of the system.

Unfortunately, this approach also bears an externalist trap. A systems intelligent actor in a simulation does not wish to externalize the system or push it away to see it more clearly, she wants to immerse herself in the system and learn from it directly. Mental models may be tuned by simple dissection of the systems but tacit models and coping capabilities need contact with the system in order to develop. In this sense, it is not solely advantageous to use simulations as tools for externalization. It can be necessary to be able to immerse oneself in a simulation and to be able to “think real thoughts and feel real feelings” (Weston 1996) to properly get in tune with the system that is being simulated and to be able to develop a feel for it.

Transcending Context

In addition to immersion in a simulation, one aspect of the simulative learning experience which should not be overlooked is the importance of context. Learning new principles of interaction and laws of system behavior is quite possible in a simulation, but unfortunately the lessons learned do not automatically apply to other situations. People trying to learn by simulation must be able to transcend context and be able to see a more generic framework in the background.

It is not by any means obvious that just knowing about something induces behavior based on that knowledge. An everyday example of this would be the people who smoke. Although it is widely known and largely undisputed in this day and age that smoking is very detrimental to an individual’s health, a large percentage of people steadfastly cling to this habit. Even though they know that in the long run they’d be much better off quitting, in the short term they end up lighting another cigarette. Just because they know of its health effects doesn’t mean that they have been able to internalize this knowledge to the extent that it would affect their behavior.

This means that in some sense, it is necessary to be able to believe in the simulation and believe that the lessons learned therein are real and can be applied to the real world and not just the world of the simulation. Both mental and tacit models are, in a sense, principles which guide us in interactions with the world, and something that is not credible and concrete might not change them at all. Take for example the smokers, which obviously in some sense do not believe that smoking is *truly* harmful to them, or at least that they are better off smoking than quitting.

Senge (1990, pp. 175) categorizes attempts to develop mental models into two categories: reflection and inquiry. Reflection involves scrutinizing the way mental models are formed and how they affect our actions. Inquiry skills have to do with interpersonal communication. He also discusses the way our “espoused theories” differ from our "theories-in-use", by which he means that our professed views differ from what we actually do. In Senge's view, this is not a catastrophe or something that should be gotten rid of, but rather a possibility to close the gap and and thus develop. Smokers would do well to take their espoused theory (smoking is bad for me and I intend to quit) and their theory-in-use (smoking's never done me no harm, and it'd be a pain to quit) and close the gap between them.

Gary Johns addresses contextuality in his paper, "The essential impact of context on organizational behavior" (Johns 2006). His main point in the paper is that context is something that should not be dismissed and factored out from scientific studies. His opinion is that scientific studies try to extract the essence from a phenomenon to generalize it, and this is detrimental to the understanding of the issue in question in the long run. Even though this may apply in many scientific studies, it is also what the human mind is prone to, and what happens in the formation of mental models. This is what Senge calls making "leaps of abstraction". Leaps of abstraction occur when our minds make abstractions to do away with a clutter of details and instead arrive at a simple concept. Considering how limited our cognitive capabilities are in specifics (as evident in, for example, the lack of perfect recall) it is obvious that the human mind must do away with context, at least to some extent, and concentrate on more abstract features. Doubtless there is a sweet spot somewhere between complete abstraction and pure data, and this sweet spot may very well be the tacit models our minds construct when trying to make sense of incoming data concerning, for example, good business practices.

Making Mental Models more Malleable

When new experiences are available and enough information is available about them to make correct inferences and generalizations from them, all that remains to be done are the changes to the mental and tacit models. This process is, of course, automated and constantly ongoing, but not necessarily very efficient.

A striking example is one that the developer of the business simulator the author partook in, Juuso Töyli, related. A team of executives from a large Finnish company took part in a session of the game, and had prepared a "winning strategy" as well as "impeccable" modelling tools for monitoring their performance in the game. They led their company in the game the same way they had always done in real life. When their calculations did not match the calculations of the simulator and their game performance did not match their expectations, they declared that the simulator was flawed and marched out of the game.

Peter Senge (1990, pp.165) brings up another example. When Japanese auto makers were gaining a large share of the American market, U.S.-based companies began to be worried about the fierce competition from overseas. A group of auto executives travelled to Japan to witness firsthand the source of the competitive advantage of the Japanese companies. However, they were unimpressed, and one executive said, "They didn't show us real plants. There were no inventories in any of the plants. I've been in manufacturing operations for almost thirty years and I can tell you those were not real plants. They had clearly been staged for our tour." Today, we know that one of the cornerstones of lean manufacturing, the manufacturing philosophy that granted the Japanese their advantage, is minimizing (or even eliminating) inventories. But the executives' mental models, which included the notion that manufacturing plants must feature inventories, would not allow for this possibility and the source of the Japanese success remained a mystery.

Even if we disregard such adamant resistance to learning new things, it could be argued most people can see some of the very same disposition in themselves, and if they do not, they should. It is plainly obvious that should our expectations (be they based on intuition, calculation or simulation) be different from observations of the real world, it's the source of the expectations that should be corrected. However obvious this seems, not many of us can claim to have truly taken it to heart.

How to tackle this problem then? If resistance to change and adherence to working, if suboptimal, methods is a proven tactic we utilize almost subconsciously, how can it be overcome? First of all, it is necessary to recognize the mental models. This can be difficult though, since biases tend to make them hazy and intangible. One method of working toward knowing them is to study the heuristics which are in a sense their offspring. A relevant example in a business context is a person's risk-aversiveness. Even though it can be hard to determine which factors have shaped the model, it is reflected in an abundance of heuristics, which are easier to study with introspection. Once a person knows at least a rough outline of his mental model, it is easier to start probing for related biases and their effects on interactions with other people (who may have different conceptions about risk) and on their decision-making.

What is also important to consider is that because in simulations there are no real dangers of any kind, it can be easier for a person to try out new approaches to situations. Mental models and ideas are not the lifeline in survival they often seem to be in everyday life, but something that can be shifted and molded to new shapes. This links to the idea of taking theories lightly, like Donna Orange phrases it in her book: "In this conversation I argue for holding some basic attitudes. [...] A second value or attitude concerns the importance of fallibilism, the commitment to hold theory lightly, to live with uncertainty and ambiguity, and to be always prepared to revise our views. This attitude keeps us constantly ready to learn something, from our patients and from each other." (Orange 1995) While she was speaking of psychoanalysis, the idea carries on to other domains very naturally. Senge tells a story which serves an example of holding theories lightly, in the words of a Harley-Davidson senior executive: "I hear more and more people say, 'This is the way I am seeing things' rather than 'This is the way things are.' It may not sound like much, but the former leads to a different quality of conversation."

Conclusions

Even though our understanding of causal diagrams and the evolution of the system states of complex systems over time is severely lacking, one does not need to despair. We as human beings possess intuitive tools for comprehending the world and these tools, combined with modern possibilities such as business flight simulators, can make these systems more understandable and controllable. We must not limit learning to simply mean the evolution of our conceptual tools and frameworks, but also include the non-conceptual, tacit learning exhibited by true masters in several fields. A concept of "tacit models" was introduced to portray the non-conceptual models in our minds. Learning also includes learning to lift the lessons learned from a specific context and being able to transfer the knowledge garnered to other situations.

This paper raised five broadened viewpoints to simulations. Simulations are a part of nature and can serve to improve both individual and team performance. For simulations to be most effective, the "feeling for the system" must be maximized and the ability for immersion in the simulation be facilitated. Systems Intelligent actors also feel no compulsion to externalize the system, but to immerse themselves in it, although conceptual externalization also has its merits. In addition being able to experience the simulation, for it to bear fruit it is also important to "hold theories lightly" and be able to carry the lessons learned to other contexts and situation. It is important to recognize one's fallibility and to be aware of the compression of raw perception into mental and tacit models.

Although several shortcomings regarding our ability to comprehend abstractions can be identified, our ability to cope must not be underestimated. Like Hämäläinen and Saarinen (2008) wrote, "In the systems dimension, humans have remarkable abilities to learn and to improve even in the absence of explicit objective knowledge." The human mind is wondrous in its ability to bend to different situations and demands, and with some nudges toward the right direction can master diverse fields. Maybe in the future, simulation can help learning in many disciplines and walks of life, and on all levels of the intellectual hierarchy. In this pursuit, human nature must not be underestimated or forgotten, but embraced.

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