24 A dynamic systems approach to the life sciences

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Each of the chapters in this book points to expanding our understanding of the multiple and complex relationships that surround development through the lifespan. In this chapter, we as the organizing committee of the Council for Human Development give a brief description and overview of the science of dynamic systems that is exemplified in the other chapters in this book. The goal of this chapter is to help people see how dynamic systems research helps us to understand human development and how it can assist in creating relevant policies and funding priorities.

The dynamic systems approach is fundamentally different from existing ideas about simple cause and effect. It begins with the realization that the living world is too complex for any one factor to have a significant effect on an outcome in the absence of many other competing and cooperating factors, all of which change over time. Dynamic systems scientists, such as the authors of the chapters in this book, seek to understand certain aspects of this constantly changing network of mutual influences according to their focus of study. The core of the notion of "system" is that it shows the relation of the "whole" and its "parts." To think about dynamic systems means that we have always to consider the history of how the system under study – be this a single child with autism or an inner-city neighborhood – changes over time.

In a few rare cases, a prior condition, or the combination of prior conditions, can be said to be a direct cause of an outcome. Hitting the "s" key on a keyboard causes "s" to appear on the screen; hitting the same key while holding down the shift causes "S" to appear. This is *sequential or linear causality*. In nature, however, instances of linear sequential causality are the exception rather than the rule. In many cases, illustrated by some of the chapters in this book, factors affect each other in mutual and simultaneous ways as they resonate and synchronize with each other. We call this *systems causality*.

Take, for example, the case of an automobile accident, which would seem to exemplify linear causality. Even in this case there are complex factors that conspire together to create the outcome. To be sure, we often highlight a single critical factor, such as that the driver was drunk or the road was slick. But injuries depend upon many sudden, dynamic, and concurrent events surrounding the accident; on whether drivers wore seatbelts; on the type and condition of the automobile, and the like. Even in this apparently simple example, systems causality is operating.

A legislative policy debate is another example of systems causality. As speakers are presenting their "point of view," they are always adjusting their words, gestures, and body postures in relation to what they perceive to be the emerging responses of the opposition. In order to get legislation passed, the sponsors of the policy need to construct their argument in terms of what they think will convince the other side. Even before a floor debate occurs, each speaker is influenced by systems causality in seeking to create a mutual, shared, compromise position. While the debate happens on the floor of the legislative body, aides and constituents are simultaneously talking and negotiating. What goes on at the same time outside the chamber is just as important as what happens inside. Nothing in the process is linear or direct. This is even true – in fact, especially true – in cases where legislative bodies repeatedly find themselves unable to reach any consensus, even though individual members desperately wish for such an outcome.

How would a scientist, such as one of the authors of this chapter, seek to understand this complex, systems causal legislative process where important decisions and turning points take place unexpectedly, in the heat of the moment, without anyone being able to trace a clear linear sequential pathway to how the decision was made? And how would such an understanding enable the actors involved to overcome the impasse in which they find themselves? By the end of this chapter, we will return to this question.

In reality, all social and biological processes are as complex and dynamic as what happens in a policy-making body. For example, how can we address the long-standing and apparently insoluble persistence of poverty in society? Taking a linear sequential view of causality has not worked. Increasing funding for welfare assistance in and of itself, while providing an important safety net, does nothing to address the root problem of poverty and its long-term negative effects on children and families. Addressing the presumed cause of the problem, the lack of money for basic needs, does not of itself produce the intended effect of eradicating poverty.

The knee-jerk response to this failure has been to look for further causes which, when combined with each other, lead to poverty. The goal here is to identify all of the critical causes and the weight that each of them has in causing the phenomenon. Even in the most sophisticated statistical models that study the interactive effects between factors, the assumption remains that causes can be broken down into a number of independent variables that operate together in linear and predictable ways. There is no sense in these models of how the multiple factors involved influence each other in mutual and simultaneous ways.

According to a dynamic systems approach, there is no linear sequential cause or combination of causes of poverty and therefore no linear sequential solution for it. Rather, poverty is *dynamically sustained* in a society by a complex set of systemically causal relationships, both political and economic, that keep it in a steady state. Lack of money is associated, at the same time, with increased psychological stress. Simultaneously, not after the fact, stress and low income drain the person's ability for working, learning, and growing. Even when access to educational resources is available, education may be forced into a low priority by the combined effect of these pressures.

Poor neighborhoods are usually unclean and unsafe, so there is no easy escape, even temporarily, from the stress: for parents and children alike, it is constant and ongoing, not a prior sequential cause. The neighborhood may be embedded, simultaneously, in a network of gangs, weapons, drugs, death, and disease. These mutual and simultaneous influences serve to sustain the status quo and to thwart the best intentions to induce change. There is, it seems, no way to exit from the continual cycle of stress, loss, fear, and disenfranchisement. This is the down side of systems causality: the stable maintenance of undesirable situations through cycles of mutual influence.

We of the Council of Human Development (CHD) take the view that understanding the complex processes of developmental change requires a science of dynamic systems. So too does the path to understanding how to eradicate poverty, disease, war, and other social ills, as well as how to raise happier, healthy children in a nourishing environment in an educational system that promotes the creativity and achievement of each and every child. Some of us are concerned primarily to research and explain what it is to be human, while others of us are focusing on how our research can be used to create effective interventions. All of us know that dynamic systems research is not meant to uncover simple causes, because in truth they rarely exist except in the imagination. Systems scientists do not seek the kinds of over-simplified statements that cater to a media looking for "sound bites." Instead, dynamic systems research:

- seeks primarily to probe the systemic and simultaneous linkages in the network of relationships that sustain particular patterns of development over time;
- aims to uncover the possible pathways that lead to changes in certain undesirable patterns;
- attempts to discover the processes required to sustain and foster the development and maintenance of a healthy developmental trajectory, or a more desirable network of relationships needed for effective decision-making and positive social change.

Dynamic systems research, in other words, sees change in terms of systems causality. So those of us concerned to make practical use of our research know that systems don't get "fixed" or "cured" with a simple formula. Rather, the "bad" system must be allowed to transform slowly over time, systemically, into a "good" system. ***In dynamic systems science, we seek to understand the laws of transformation.***

What is a dynamic system?

A dynamic system is a network of overlapping relationships that exist simultaneously. We could see the whole world of living things as just such a network, but as dynamic systems scientists concerned with understanding human development, we take as our focus particular aspects of this massive network. At the same time, we recognize that the demarcation of domains of study is a matter of research convenience because, as systems scientists know, these systems are bound to inform one another.

The *intra-personal system* takes account of relationships between the various systems of the body and mind, such as between genes and their cellular environment, between brain and behavior, between muscles that act together to perform an action, or between emotion and intellect.

The *inter-personal system* includes social relationships such as, in many organisms, those between parent–child and close companions; and in humans, the same types plus teacher–student, supervisor–employee, therapist–client, romantic partners, business partners. Relationships between humans and their physical environment are also in the interpersonal system. When we relate to, and care for, the animals with which we share our planet, and in some cases our homes, we build interspecies relationships.

The *socio-cultural system* contains all the relationships within and between groups of people with intersecting histories; it takes in relations of international peace or conflict, systems of kinship and religion, of politics and economics, institutions of education or medical care, systems of government and law.

The working groups of the CHD (Anthropology of Human Development, Biology and Development, Ecology of Human Development, Evolutionary Perspectives, Geo-Political Contexts of Development, and Mental Health and Development) encompass all these systemic relationships. There are specific research methods that apply to each domain of relationship and that are used by scientists in each of the working groups. Understanding gene action within the cellular environment requires very different techniques (see Tim Johnston's chapter, part I of this volume) than those used by the anthropologist who tries to grasp relationships within a large group of people and their ideas about the world around them (see Christina Toren's chapter, part III of this volume). This chapter, however, discusses some of the more general notions of dynamic systems science that could potentially apply to all these areas of investigation.

Most research in the life sciences has tended to use linear sequential models of cause and effect that are statistically manageable and conceptually straightforward. These models are of the form: A precedes and causes B to occur. Taking a particular drug is thought to lead to a cure for a disease. Teaching more mathematics and reading skills is thought to improve standardized test scores. Increased welfare assistance (or creating more jobs, or providing basic skills training, or something else) is thought to lead in a linear causal way to the alleviation of poverty. While these linear causal ideas often serve as a first approximation to the way nature works, they do not take account of the "big picture." As Gilbert Gottlieb and Carolyn Halpern point out (part I of this volume), a dynamic systems approach emphasizes "relational" causality. Traditional methods of observation and experimentation are based on the idea of holding everything in a situation constant except one factor, which is allowed to vary. However, factors do not act in isolation. Gottlieb and Halpern emphasize that what makes developmental outcomes happen is the relationship between two or more factors, not the factors themselves.

Dynamic systems research principles can be used by scientists to get closer to the "big picture." What's in the "big picture"? *The "big picture" contains a description of the complex relationships between parts of a whole system, and how that system functions in real situations.* The "big picture" also shows how systems transform over time. How do relationships early in life transform into emotional well-being or mental health problems? How do situations of international conflict transform into states of war or eras of peace? The "big picture" helps us to understand how complex systems of relationships change over time so that we may come to know the factors that regulate systemic change toward particular outcomes. The focus is on systemic causality – how the whole system transforms – rather than on simple fixes.

As Michael Kerr shows, this approach has had a dramatic impact on family research. In this case, taking the "big picture" means seeing the family, not as a collection of psychologically autonomous individuals, but as an entity or "organism" in its own right. That is, all of the members of the family are bound together in a highly interdependent relationship system. This discovery has enabled family systems therapists to answer long-standing questions that could not be explained on the old linear causal models, such as, why we see such disparities between siblings in a family (Kerr, part IV, this volume).

Traditional research about linear cause and effect

As Stuart Shanker describes in his chapter, our thinking about mental health and mental illness have long been and continue to be governed by a philosophical picture that assumes that mental disorders are the direct effect of linear causes (Shanker, part II, this volume). The result is a pronounced oversimplification of the complexity of mental disorders. As Stanley Greenspan highlights in his chapter (part IV, this volume), among the oversimplifications has been a tendency to focus on the genetics or genetic susceptibility to different mental illnesses without adequate understanding of the experiential and environmental factors or even metabolic factors that influence genetic expression.

To appreciate the significance of this point on a larger sociological scale, suppose we want to know the effectiveness of an educational program meant to alleviate the effects of poverty in an inner city neighborhood. The goals of the program are to help people to understand their options, seek educational resources for self-improvement, and reduce stress so that they can focus on self-improvement instead of simply fighting to stay alive.

A traditional research approach would be to measure indices of achievement – such as income, employment, stress levels, completion of educational training programs, etc. – both before and after people's attendance in the program. How does the traditional approach draw its conclusions from these measurements? This is done using statistics that show whether the group as a whole increased their levels of income and achievement after the program was completed compared to before. This seems like a perfectly reasonable metric and indeed it is the currently and widely accepted way to do research on program effectiveness.

This, however, is not the whole story. In fact, from the perspective of a dynamic systems scientist, this is a highly limited and in some cases even a misleading story. To understand why, we will first look at the meaning of these particular statistical methods for inferring program success. Second, we will look at what else would be important to know in evaluating this program.

The statistical methods used in the traditional research approach are statements about averages. Thus, one could say that *on the average*, people who attended the program improved. But how much, *on the average*, did they improve? Perhaps there was not enough of a change to make a contribution to their lives over the long run. Traditional statistical methods seek universal statements. Dynamic systems methods focus on individual difference and variation. Just to say that people improved does not tell us what that improvement means to them, nor does it say how much of an improvement is enough to make a real difference for them. Dynamic systems scientists would seek to preserve for study and analysis the measures for each individual, rather than losing information about individuals by computing a statistical average. All too frequently, however, it is just such simple statistical statements that justify the investment of large sums of money from government and private sources into programs whose ultimate effectiveness is not well understood.

Improvement of people *on the average*, however, is also a problematic way of thinking about human and social change. *On the average* means that some of the people improved more than others. In fact, it could mean that some of the people did not improve at all and some actually became worse off after the program than before. A handful of people who benefited a great deal could raise the average, making the program seem more effective than it actually is for most of the people who attended. This is why statements about averages can be highly misleading, and why systems scientists endeavor to keep track of individual change, for example, by computing how many individuals improved and how many did not. Another approach is to form sub-groups of individuals – say a group that improved a great deal, a group that improved moderately and a group that did not improve – in order to better understand how these groups may differ.

The fact is that in every program seeking change, some people will do better than others. Some children are academic stars in school while others are seen as failures or drop-outs. Some families will rise above their poverty with or without a program while others make little or no progress even with a great deal of resources given to them. It seems important to understand how these individuals and families progress through the program: at what point do they excel or fall behind? Are there particular program features that work for some people and not others? Dynamic systems scientists would want to make frequent measurements on people throughout the program. They may use the same measures as the traditional scientist but assess them more frequently, to show the ongoing progress of change and to preserve information about how each person changed, for better or for worse.

The traditional research methods cannot address these issues of change processes in part because they focus on averages and in part because they often fail to observe people while they are actually in the program, relying instead on "before" and "after" snapshots of their lives. This is not to deny the importance of the valuable research that has been done on the relationship between socioeconomic status and various aspects of child development. Rather, this relationship should be the subject of much more detailed research. In other words, large population studies are not an end in themselves, but alert us to the need for the focused lens of systems analysis.

Another fact about social or educational programs is that the professionals who deliver them will never teach identically the same program twice. Professionals always adjust their teaching or consulting to the needs of the particular group. What's more, even in the same group going through the same program at the same time, the professionals are likely to treat each person a little differently. These small differences may make a big difference for particular people, whose success in the program may depend on whether they trust or respect that professional. Dynamic systems scientists would want to assess the changes in behavior and attitudes not only of the program participants but also of the program providers. A systems approach which focuses on relationships would assess the way in which the participants relate to the providers, not only before and after but at many points in time during the program. Because traditional research does not study the program and its changing implementation over time, focusing instead on measurements taken before the program begins and then after its completion, there would be no way of knowing how that particular program affected each different participant or how the program staff made adjustments to each person.

The same point applies to education. The effective teacher adjusts her teaching to the needs and abilities of every individual child. But when classrooms are too large to allow for this sort of individualized attention, it invariably happens that those children who may need the most attention end up getting the least, as is reflected in the overall class averages measured by the standardized tests mentioned above. The linear sequential response to this result has not been to enhance the teacher's ability to meet the individual needs of her pupils, but rather, to remove any variability in teacher performance by carefully scripting how teachers should deliver their lessons (in extensive marginal notes in the teacher's textbook). Far from curtailing the poor results observed in schools in many lower income areas, this strategy has actually exacerbated the problem by further reducing the creativity of teachers who were already feeling overwhelmed by the constraints in which they are operating.

Traditional research cannot provide a complete scientific basis for policy decisions

Thus, there are indeed many ways in which the traditional approach to research gives us limited and sometimes even misleading information. Yet policy-makers in government and private settings may only have this *on the average* information at their disposal. The traditional research is used in so many different settings that it may seem to be the only available and credible source of scientific evidence. Private and government funding agencies often assume that their approach is integrative, capable of taking all complexities into account, just because multiple measurements are used to assess change. They may even assume that the traditional research method *is* science, the only meaningful form of doing research.

Traditional research is used, for example, when testing the effectiveness of drugs for treatment of mental illness. Results of such tests are stated in terms of averages and percentages. A certain percentage of people are said to "improve" on the drug. But what constitutes "improvement"? In the case of clinical depression, improvement might be measured in terms of the subject's eating and sleeping patterns, with no thought given to their overall sense of well-being, their ability to form meaningful relationships, take pleasure in their job, etc. In other words, what constitutes a "successful" treatment is reduced to terms that are commensurate with the sorts of changes that can be produced by the drug in question.

Or consider how a certain percentage of people have serious side effects to a drug. How does a person decide if he or she might be the one who might have a serious side effect? Traditional research can't say because it does not typically study how particular people with particular characteristics fare with the medications. The National Institutes of Health in the United States have only recently begun to study the effects of certain medications on women and children. In the past, dosages and effects have been determined largely from samples of adult men.

Interactions between one drug and another are not sufficiently known since only one drug at a time is typically investigated.

Traditional research is also used when school programs are tested for their effectiveness using standardized tests. What makes an achievement test standardized? Items are selected for the test in such a way as to allow for half the children to score above average and half below average, the so-called "bell curve." In other words, the test itself actually manufactures an "average" student who only "exists" by virtue of the way the test is constructed. Aside from this, all the same problems that we saw for poverty programs exist for interpreting the results of the standardized tests in relation to the effectiveness of an education program. What we really need to know is how each child does in school. Why does one method of instruction work only for some children and not for others? What does each child need to optimize his or her learning potential? As Ken Richardson (part I, this volume) points out, the interactions between social structures and regulations and personal histories is the source of the amazing mental diversity found among people. *On the average* research can't help us here. There is another kind of social and behavioral research that is also scientific and which provides a powerful tool to answer these questions: dynamic systems science.

Dynamic systems science provides a picture of the real-world that can facilitate policy decision-making

There are some major and important differences between the traditional scientific methods and scientific methods based on a dynamic systems approach: We examine these differences and discuss the implications for making policy decisions based on dynamic systems research. Though our examples focus on programs, the same principles apply to understanding processes through which groups of humans (or other animals) spontaneously cooperate to solve some task, develop skills of communication or language, and so on. A strength of the methods we discuss here is their broad applicability, as reflected in the diverse chapters in this book.

Dynamic systems research principle 1: focusing on particular cases rather than averages

Dynamic systems research focuses on relationships within and between particular organisms, persons, groups of people, and populations. In the example of the poverty program, above, dynamic systems scientists would assess the relationship between participants and program providers, and the relationship of the participants with each other. This could be done by interviews, questionnaires, or direct observations of how each person related to the others and how that relationship affected their participation and achievement. Dynamic systems research is based on case studies rather than the "average" person and the focus is on how that particular person understands, interacts with, and utilizes what is made available in their relationships with the staff and other program resources. In the poverty program research, for example, it is important to understand how each person was affected by their participation.

In other words, systems analysis provides us with the sort of focused lens that is needed for discovering vital relationship *patterns* that a larger lens will not detect. As Beatrice Beebe and Joseph Jaffe describe it, dyadic "microanalytic" research operates like a microscope, identifying in detail the instant-by-instant interactive events which are so fast and subtle that they are usually lost to the naked eye (ear), and operate largely out of awareness. Their own work illustrates how microanalysis uncovers aspects of nonverbal communication that the unaided human brain simply cannot report (Beebe and Jaffe, part IV, this volume). Similarly, George Downing describes how video microanalysis gives an access to the nitty-gritty of what is going on in relationship disorders, which is difficult to achieve by other means (Downing, part IV, this volume). In fact, by building on Beebe and Jaffe's approach to therapy, he has been able to show that such "video microanalysis therapy" can provide us with a remarkably rapid and effective way to change what is happening between parents and infants, or parents and children.

To think in terms of patterns of communication, of social processes, or of life, therefore, is a defining characteristic of dynamic systems thinking. Patterns permit abstraction in science without eliminating difference, variation, and the uniqueness of particular human beings.

Suppose, to take one example, that poor single mothers who had the support of the child's grandmother are more likely to reach higher levels of education or job training at the end of the program compared to single mothers who did not have family support. An immediate policy implication is to fund alternative child care for single mothers who do not have family child care as an explicit part of the program. This additional program component is likely to enhance the effectiveness for those particular mothers, which then makes the program as a whole more successful.

This increased program success could be measured using the traditional before–after *on the average* approach, but that does not take account of systems causality. From a dynamic systems perspective, an increased number of success stories that emerge *during* the program is likely to influence all the participants, even if they do not fall into the single mother category. Because of systems causality – the simultaneous and spontaneous emergence of mutual effects – a kind of "critical mass" of enthusiasm may be achieved that boosts everyone's involvement with and commitment to the program. Dynamic systems research would more easily capture this phenomenon because it would have assessed each person's relationships with others on a frequent basis, so that the researchers can track the changes in mutual enthusiasm, or for that matter mutual conflict, as they unfold during the program.

Dynamic systems research does not focus on single measures of each person but rather on the whole person and the relationships and conditions that inform their life. People cannot be characterized by a simple set of numbers. It makes an important difference whether a single mother has good child care or not. This difference cannot be captured by a simple index of her success or failure. A dynamic systems scientist is likely to obtain measures not only of a person's success or failure in the program, but also of their general well-being, hopefulness for the future, and impacts on other family members. More detailed systems analysis may consider changes in the family, neighborhood, and community to consider how the program's effects may or may not "spread" into the larger social system.

On a much smaller scale – or much larger, depending on how one looks at it – this approach can, as Stanley Greenspan outlines, have an extraordinarily powerful impact on one's understanding of an individual child's developmental disorder, and how to best treat it (Greenspan, part IV, this volume).

Scientific validity and power is achieved by comparing and contrasting different case histories with each other. Careful study of each case individually and then together can begin to reveal the similarities and differences more clearly. Scientists using this approach can come to a general conclusion that applies to many people, but this conclusion comes from the hard work of observing each person individually and then looking for common factors and processes.

This method of comparing and contrasting takes into account that no single set of either research methods or research findings applies equally well to all human populations. People's experiences and understandings of the parameters under discussion here – what they embrace, what they avoid, what they admire, and what they aspire to in their lives – differ in structured and patterned ways as a function of each person's history. This personal history is one aspect of the history of a particular family and its relationships with other families, which are themselves embedded in the history of relationships between much larger social groups.

Dynamic-systems anthropologists, for instance, can learn about the factors that a person considers important in their own history and family history by talking and listening to, and living with, people "in the field" – whether in New York City or Tokyo, the mountains of Papua New Guinea, or rural China. When they come up with a set of findings for one population, they do not automatically assume it applies to another.

Further, within any population, exceptions to the general rule always occur and the scientist can use this case comparison method to better understand differences between people so that more effective interventions and policies can be tailored to meet everyone's needs. No person need be left behind because this type of research considers the whole person, rather than aiming for a particular test score or outcome measure.

Dynamic systems research principle 2: making multiple observations of the way in which each particular case responds to changing circumstances rather than only one observation before and one observation after

Dynamic systems research seeks to observe particular cases all during the process of change: before the program, during the program, and after the program to better understand who succeeds and who falls behind, when, and why. Typically, this is done by making multiple observations on the same cases. Let's suppose the program lasts fifteen weeks. Instead of just two observations (before and after the program) in the traditional approach, a psychologist might observe people weekly, beginning before the program starts and continuing until after the program is over. With eighteen or twenty observations on each person, one can get a much clearer sense of their progress through the program, their ups and downs, when, and why they occurred. An anthropologist might even join the program herself, observing others from the position of participant and deriving a near-continuous account of change over time, supplemented by before–after interviews.

Continuing the example from the poverty program, the dynamic systems scientist armed with multiple observations on each person, as well as multiple observations on the whole group during meetings or classroom discussions, can create a real-life picture of how each person changed over time in relation to the events that took place in the group sessions. This is a way of fine-tuning our understanding of what works and what does not work for each person. Elements introduced early in a program may have a greater impact if they are introduced later.

Experiments can be done by creating variations on the program differing in sequence or timing of components.

From a policy perspective, it is considerably more cost effective to adjust components of a program and the way in which individuals interface with those components, than to reject programs summarily that fail to show an effect *on the average*, or to continue funding poor quality programs that do show an effect *on the average*. Contrary to the assumption that has guided policy-making over the past fifty years, *on the average research* is not a sufficient tool for making informed policy choices when funding is limited and needs are great. *A fine-tuned, case-based documentation of the real-life histories of change over time for the people in the program, in the hands of a dynamic systems scientist, can give a policy-maker a much more sensitive tool for allocating precious resources.*

Dynamic systems research principle 3: accounting for how a whole system of relationships changes over time, focusing on this whole system and its transformations, rather than on an idealized average individual, who by definition has no history

Dynamic systems research takes account of the fact that the features of the program will change as the people who deliver it and the people who take the program mutually and simultaneously adjust in their relationship to each other over time. *This means that the "program" is changing over time, not a static entity that either works or does not work.* Dynamic systems research is based on the notion of a web of interrelations. It also means that change may occur "in the moment" as a result of a shared and simultaneous convergence or divergence between people, rather than as the result of a step-by-step pre-planned sequence of events.

Everyone knows that teachers, parents, supervisors, counselors, therapists, and other service providers are not machines that stamp out identical replicas of themselves each time they repeat what they do. Everyone also knows that the most effective leaders are those who can dynamically and creatively adjust to each individual circumstance while still applying their set of skills and accrued wisdom. And if our teachers are not allowed any scope for freedom and creativity because of the introduction of the sorts of rigid teaching tools described above, or even worse, a shift from personalized teaching to classroom situations that rely primarily on computerized forms of instruction, how can we expect their students to develop the sorts of creative, reflective thinking skills that will be needed to address the challenges of this new century?

So, whenever scientists who study programs use the before–after *on the average* approach, they may be missing these creative moments that could make or break a program. They are reducing real-life to the simplification that the "program" is static, fixed, a product to be delivered, exactly the same each time. Social and biological systems are simply not machine-like. They are alive and they grow with experience.

Money and resources don't just go to programs but to people who participate in those programs. Dynamic systems research can inform policy-makers about these human characteristics that enliven a program. Policy-makers need to know whether program administrators allow for flexibility, creativity, sharing, and growth in the program staff. Is there a team spirit that wants to make things better for providers and participants? Does the program provide for training and development of project staff? Are there ways for staff to seek advice and new ideas for what they may encounter each day? If the assessments of the program are based on people's perceptions and evaluations of their relationships within the program, then all of these dynamic processes may be documented for further study.

Dynamic systems research is based on the possibility for spontaneous emergence of new discoveries. This means there is something that can only happen "in the moment" when two or more people are fully engaged with each other: the sparking of new ideas, thoughts, feelings, and ways of acting. Co-creativity cannot be planned in advance, nor is it the result of step-by-step linear sequence of events. Co-creativity is a product of systems causality that can only happen via simultaneous and shared commitment. A dynamic systems scientist taking this point of view can use observations and self-report measures for judging whether relationships are creative or whether creativity is hampered. These measures of opportunities for creativity may reveal a great deal more about the origin of desired outcomes than any specific characteristic of the individual or the program.

Dynamic systems research principle 4: including the scientist as part of the changing environment of the system being studied rather than assuming that the scientist does not in any way affect that system

To say that the scientist affects the system is not the same as saying that the scientist is biased or that the scientist deliberately acts to change the outcome of the research. Rather, it is another instance of recognizing the complexity of the real world. According to international guidelines governing research on humans and other animal species, scientists are obliged to obtain consent to do research whenever possible and to protect the safety, rights, and privacy of their research subjects. So, it is impossible for a scientist to be unobtrusive and without any effect at all on the system being studied because participants know they are being observed.

But the scientist's involvement with the system being studied is much more rich and complex than just obtaining consent. There is a myth in society that scientists – who people imagine always wear white coats and carry clip boards – are dispassionate, objective, and emotionally cold. Nothing could be further from the truth. A study of the lives of the most famous scientists – Galileo or Einstein in the past, Jane Goodall or David Suzuki in the present, for example – reveals that they all have an emotional connection to what they study: they care about it enough to invest their careers and lives in that work. Scientists are also part of the social, political, and religious factions and controversies of their time.

Dynamic systems scientists accept the humanity of the scientist as part of the complexity of the system being studied. They do not try to be detached "objective" observers. Once this leap of acceptance is made, however, it creates an entirely new meaning of the word "scientific." *To be scientific means to find a way of engaging with the real world and at the same time to describe explicitly and openly how that world is concurrently being affected by the scientist's engagement with it.* The scientist becomes part of the system to be observed and as such may become part of the systems causality.

To apply dynamic systems research methods, it is often the case that extended participant observation, in which the scientist actually becomes a living and working member of the system, is essential. This is often the case in anthropology and sociology, as we have seen. The scientific discipline of writing the field notes made by the participant observer is capable of revealing to the scientist what the scientist may take for granted. In such a case, to be able to lay bare what is taken-for-granted and to ground one's analysis there requires, for example, systematic data on the way that relations between people are projected into their lives and made concrete in the rhythm of the day as this is lived in the context of the particular program or process being studied.

Scientists often work together in teams so that each different scientist's perception of the world being studied is itself a case study. Similarities and differences between each scientist's point of view become part of the process of understanding the whole system from the perspective of how different human scientists relate to it. The result is in fact a much more accurate view of reality because it is holistic and not based on the viewpoint of one privileged observer who has all the power and authority to make judgments about the "correct" view of reality.

Rather than ignoring one's effect on the system in the name of objectivity, the dynamic systems scientist is highly trained to be constantly exposing his or her judgments and biases in order to be critically examined by self or others. Collaborative scientific work is not very different from the policy-making process in a legislative body. Dynamic systems thinking considers that we are able better to understand nature and human problems, but we do not think that our knowledge is the last word. There is always an open door for indetermination, innovation, and new levels of complexity and precision in the process of scientific discovery. Just as what happens in any dynamic system is a co-creation as people interact and change over time, science is living and breathing, changing and being created, until some kind of convergence is reached about the nature of a process of change, or about the life of a particular individual or group being studied.

Conclusions

We now return to the example of how policies are made in a legislative body. In the traditional approach, we could simply do a straw vote of the members before the negotiations begin and compare that to the actual vote on the floor at the end of the negotiations and debates. We could see how many minds were changed and whether the policy was or was not approved. This type of information has a certain utility in the news media and certainly the vote matters to the lives of those affected by the policy.

But from the perspective of the policy-making process, the traditional approach says virtually nothing. Each legislator personally learns something valuable from each debate and each vote. No matter which side they took, each person learned a little more about how to better present their position, about who could be counted as an ally, about how to use constituent and advocate input, about when in the process of negotiation it is better to act and when it is better to remain silent, and the like. What the legislative body is really about is the ongoing and dynamic relationships between these different groups and finding, for each particular legislator, more effective ways to maneuver. In their learning process, each legislator is implicitly using dynamic systems methods of research and not traditional scientific methods.

Dynamic systems scientists combine a similar sensitivity and respect for how the real world operates in all its changing complexity with the tools and training of a research scientist. Dynamic systems scientists may use statistics that describe how individuals change over time rather than statistics based on averages. As scientists, it is their job to fully get to know how the members of any system – in a chimpanzee group in Tanzania, a Canadian family, or a rural village in Madagascar – behave, think, feel, and act. Dynamic systems science is as messy as the real world. The scientist, however, is trained to see patterns that emerge out of that complexity after a long period of observation and personal engagement with the particular system under study.

Dynamic systems research is a more costly investment in the short run. Because the focus is on multiple observations of particular cases and examining multiple factors that make up the whole system or whole person, relatively few cases can be studied at any one time. Funding dynamic systems research is placing a bet on quality over quantity. The dynamic systems scientist may work more slowly but the yield is detailed information that is highly meaningful to the making of policy decisions. Over the long run, dynamic systems research can build a complete picture of the human transformational process that will give us a better understanding of how each human life is lived, the environments that optimize each person's growth and development, and the most effective ways for policy-makers to allocate precious resources.

Basic principles of dynamic systems science

- The living world is too complex for any one factor to determine an outcome in the absence of many other factors, all of which change over time
- In the living world, multiple factors influence each other in mutual and simultaneous ways
- The manner in which living phenomena function and develop cannot, therefore, be explained by trying to isolate specific causes that operate in linear and predictable ways
- To understand how living phenomena function and develop we need to understand:
    - the complex relationships between parts of a whole system and how that system functions in real situations
    - the history of how the system under study changes over time
    - the systemic and simultaneous linkages in a network of relationships that sustain particular patterns of development over time
- Dynamic Systems Science (DSS) focuses on how a whole system of relationships changes over time, rather than on an idealized average individual

- In place of the sophisticated statistical methods that traditional research uses to arrive at generalizations about *population averages*, DSS focuses on individual difference and variation
- General conclusions that apply to many people are made on the basis of careful study of each case individually which, together, can begin to reveal similarities and differences
- This sort of fine-tuned, case-based documentation of the real-life histories of change over time is critical for making informed policy decisions
- DSS aims to uncover the possible pathways that lead to significant changes in highly entrenched patterns
- In practical terms, DSS attempts to discover the processes required to sustain and foster the development and maintenance of a healthy developmental trajectory, or a more desirable network of relationships needed for effective decision-making and positive social change
- DSS recognizes that the scientist is part of the changing environment of the system being studied
- The DS scientist is trained to see patterns that emerge out of complexity after a long period of observation and personal engagement with the particular system under study

SUGGESTED READINGS

Bergman, L., R. Cairns, L. Nilssom, and L. Nystedt (2000). *Developmental science and the holistic approach*. Mahwah, NJ: Erlbaum.

Fogel, A., A. Garvey, H. Hsu, and D. West-Stroming (2006). *Change processes in relationships: relational–historical research on a dynamic system of communication*. Cambridge University Press.

Granott, N., and J. Parziale (2002). *Microdevelopment: transition processes in development and learning*. Cambridge University Press.

King, B. (2004). *The dynamic dance*. Harvard University Press.

Moustakas, C. (1994). *Phenomenological research methods*. London: Sage.

Shanker, S., and King, B. (2002). The emergence of a new paradigm in ape language research. *Behavioral and Brain Sciences* 25: 605–626.

Toren, C. (2002). Comparison and ontogeny. In A. Gingrich and R. G. Fox (eds.), *Anthropology, by comparison*. London: Routledge.