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Can we be less prescriptive in our classrooms – and more successful with our students?

What Complexity Science Tells Us about Teaching and Learning

By Dr. Darren Stanley
Faculty of Education, University of Windsor

Complexity Science Research Tells Us

- The diversity of knowledge and experience is an important source of intelligence in learning systems.
- Rich learning engagements (and the making of seemingly abstract connections) occur when knowledge is seen as shared and distributed.
- Local interactions within small groups of students (and the power of self-organization) create greater shared classroom coherence and understanding.
- Complexity science principles allow teachers to think about and imagine ways in which their classrooms can become healthier and more democratic learning organizations.

DARREN STANLEY, PHD, is an assistant professor at the University of Windsor. His research interests are in the areas of healthy learning organizations; the dynamics of, and possibilities for, mathematics classrooms where diversity can be encouraged and embraced rather than controlled.

I seem to have had rather similar experiences to my students when it comes to learning mathematics in the early years of school. The images, interactions and work are generally recognizable: few or no manipulatives, worksheets with endless questions, isolated concepts, linear coverage of a unit, independent work and so on. In my classroom at the university, I typically present mathematics in a vastly different manner and way. And, while most of my students believe that something different needs to be done from what they experienced in school, I still see looks of confusion – at least I think these are looks of confusion. To be sure, they do seem to suggest that mathematics teaching looks much messier than many of them recall.

Many teacher candidates grapple with concerns pertaining to the management of a classroom and express an overwhelming sensibility about controlling its many aspects – students, curriculum, assessment, etc. As far as learning goes, the natural inclination is to simplify as much as possible what students are to learn. But how can teachers create and use complexity rather than manage it, not just for their students' benefit but for their own? Although complexity is often perceived as a liability, this monograph considers how it can be viewed as an asset and how the ideas behind complexity science might inform pedagogical practices.[1]

A New Science

Many people would agree with the notion that the world is complex. In terms of the emerging field of "complexity science," however, the term *complex* means something quite specific, especially in terms of learning and learning systems. Complexity science principles suggest that educational matters might be or even need to be *complexified* rather than *simplified*.

A new mindset is needed ...

To be sure, classrooms are neither mechanical nor anarchical – that is, learning is not a matter of *either* building knowledge *or* of simply sitting back and letting anything happen. Classrooms of children – like all healthy complex learning systems – are, or should be, more like schools of fish, flocks of birds or colonies of bees. An entirely different mindset, language and set of metaphorical images are needed to understand the classroom and its constantly unfolding dynamics when one views a classroom as a complex system. Indeed, the images of factories and production lines – something carried over from the Industrial Revolution – are simply inappropriate for contexts where learning, as a web of interconnections, unfolds.

If we return to my classroom on campus, we notice a few things. When we consider, for instance, the kinds of things that we do when we look at fractions, we see a diversity of ways in which we understand certain ideas and make connections among different concepts; some ideas and discoveries are shared while others are not and many insights are arrived at through some kind of hands-on engagement. For sure, our interactions are not so easily prescribed by me or anyone else. We discover that our learning as a whole class is very non-linear and full of redundancy and diversity in how we interact and what we learn. We are, I tell my students, a reflection of certain complexity science principles that underlie a healthy learning organization.

Principles of Complexity Science

A complexity science perspective focuses on the relational qualities of organizations of all types and scales – complex organizational bodies like neuronal assemblies, biological bodies, social collectives, bodies of knowledge, governance structures and local ecologies.[2] Complexity science is concerned not so much with attempting to isolate the parts of an organizational system as with understanding the relationships that give rise to the organizational whole.[3] In schools, there is a need to focus on a different scale, that of the classroom, rather than the individual students. Moreover, it is the activity of the classroom that needs our attention.

Such an assertion may seem paradoxical. How can one tend to the needs of individual students by focusing on the classroom as a whole? This runs contrary to centuries of thought, which has tried to reduce life's complexities to something knowable and controllable by tending to the smallest parts. In the classroom, these "parts" are individual students. Teachers are often concerned about managing classroom dynamics and making learning as straightforward as possible.[2] Complexity science, however, suggests that teachers can be less prescriptive; rather than thinking of learning as linear and sequential, teachers could be encouraged to imagine it as a web of playful possibility, where their role is to outline the "playing area," allowing for connections and insights to arise through shared class activities. When the classroom is thought about and organized in this way, it is the interactions among students and ideas that propels learning forward, what complexity science refers to as the principle of "neighbour" or local interactions.

Healthy complex organizations arise from particular conditions and organizational principles.[7] While low degrees of interaction tend to stunt communication and the sharing of ideas, too much interaction can overwhelm the classroom. A highly controlled classroom can become too rigid and fixed, whereas a classroom where power and authority are distributed ensures that, collectively, students can learn what they need to learn. Complexity science refers to this as the principle of decentralized control.

A diverse collection of students and teachers, activities and ideas affords the possibility of novel or creative prospects and the capacity to adapt. This is referred to as the principle of diversity. Too many diverse ideas, however, can bring a class to a halt. Thus, a certain level of redundancy or repetition and recursiveness of activities and ideas helps bring groups of students, or even the entire classroom, to a place where the larger collective has the capacity to move forward (to learn!), bringing into play the principle of redundancy. Our classrooms should be diverse places, but we all have shared experiences that allow us to relate to one another.

We now have a few complexity principles with which to work: neighbour or local interactions, decentralized control, diversity and redundancy.[8] When these principles are either absent or are present in unbalanced ways (e.g., too much diversity, too little redundancy), the learning organization and the people therein are unable to share, adapt and evolve.

A Look at Teaching Mathematics

A complexity science approach to mathematics opens up a greater possibility for playfulness, creativity and diverse perspectives. And, naturally, what we find, as a result, are classrooms that are "messy," tentative and all abuzz – classrooms which break down persistent negative experiences and apprehension about math.

Neighbour or Local Interactions

In the mathematics classroom, the concept of "local interactions" refers not so much to working in pairs or small groups,[10] but to the notion that our ideas need to "bump" into one another, creating the possibility for new ones.[4] In some cases, we can see a blending of new and old ideas, expressed individually or collectively, that opens up opportunities for further elaborations of mathematical ideas and structures. When the students in my class look at fractions, for instance, they engage in paper-folding exercises as a way to understand a variety of concepts and share with one another what they discover – like the commutativity law, equivalent fractions and lowest terms. More conventional, teacher-directed/textbook-based approaches break down these concepts into isolated ideas without real meaning and present them to students in a controlled and deliberate manner. Rather than relying upon a single node in a web of connections to disseminate what is required, the whole web of ideas is present, contributing to growth in understanding.

Decentralized Control

"Decentralized control" stands in opposition to "centralized control" – like "top-down" management where a single person is (apparently) in control of everything. Decentralized control reflects the idea that the actions of a group and the directions that it takes are shared and distributed. Students and teachers need to negotiate the conditions needed for learning to happen.[10] When students work together, the direction their study takes is determined by ideas that arise locally rather than "from above." A seemingly small insight from one child can suddenly change the whole focus for the class. Thus, the leadership of and direction in a class is distributed and often not held by the biggest, the loudest, the smartest or the most popular person in the class.

Diversity

Diversity refers to the range of possibilities that are present when generating, identifying and evaluating new ideas and possible actions. It is what allows a local working group to learn something new. When all students are required to produce the same solution with the same method at the same time, new and useful insights are hard to come by. On the other hand, too much diversity makes it quite difficult for a group to "stick together." So, for instance, when students explore the notion of "half-ness" by folding their pieces of paper ("hotdog" folds, "hamburger" folds, folds along the diagonal), a variety of representations arise and open up new questions and insights into children's ideas about halves of things. Why and how would folding a piece of paper in one way possibly be the same kind of "half" as folding it in another way? Using the concept of equivalent fractions allows us to easily make these kinds of diverse connections.

Redundancy

Of course, we don't find 30-something unique examples of paper folded into two halves. In fact, we find that the classroom, through its shared knowledge, shows some redundancy – *a concept that is complementary to diversity*. Some of my students notice, for instance, that many will have folded "hamburger" folds while others will have done "hotdog" folds. In other words, and as paradoxical as this might seem, classrooms need to have enough shared mathematical knowledge to develop new mathematical understandings together.[11] As a result, if a student or teacher does not contribute to the class's mathematical understanding, others in the class can still contribute productively.

Creating conditions for learning ...

What is oftentimes needed is not some tidy arrangement of isolated and isolatable concepts, but a rich mathematical engagement where students can interact with one another, share different ideas and make connections with seemingly disconnected ideas and concepts. To do otherwise, would entail prescribing the activities and outcomes of teaching, rather than creating playful possibilities. It is the difference between causing learning and creating conditions for learning. The actions of teachers do not so much determine what students learn; rather, what students learn is dependent upon our collective presence and participation in the classroom.[9]

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Some students will do different kinds of folds to show an understanding of a "half." But, even more, many are able to make other important connections with seemingly abstract mathematical ideas. For instance, some are able to show that a question like $\frac{2}{3} \times \frac{3}{4}$ can produce different representations which include, $\frac{6}{12}$, $\frac{2}{4}$ and $\frac{1}{2}$. And, moreover, they realize that the order of the operations (in the form of paper folding alone) does not matter. Thus, while the processes used to generate these results and representations will vary, we find some measure of redundancy in the class's work, remembering that the place of control in the classroom can be decentralized and local interactions help to facilitate the processes of discovery.

In Summary

This model for learning mathematics may be quite different from what teachers experienced themselves in the past where classrooms were less interactive, filled with little activity and conversation. Teachers were generally in control, directing all aspects of what was to be learned; different points of view and approaches seldom brought to the surface new ideas and insights and a high degree of redundancy meant that everybody learned the exact same thing at the exact same time.

We would do well to let go of being completely in control in the classroom and take advantage of the diversity and redundancy principles of complexity science. This is not to suggest that we need to abdicate our responsibility for planning and facilitating learning. On the contrary, it is all the more important for the teacher to know how to enhance the learning potential of the classroom as a healthy learning collective that is much more than the mere intelligence of any single student. In other words, it is up to the teacher to understand how to create the conditions, drawn from complexity science principles, for everyone in the class (as a whole, living breathing thing) to learn mathematics most effectively.

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