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The Possible Ways of Practicing Complexity Theory through Concept Study in Mathematics Class

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Abstract

This paper addresses the ways that the complexity theory can be practiced in mathematics class to encourage students' participation in learning of the mathematical concepts. The paper starts by introducing the theory and its associated attributes which are necessary to organize the class for the individual and collective understandings of the mathematical concepts during teaching and learning process. After that, the paper illustrates the ways that the attributes of complexity theory can be practiced in mathematics class under the lens of concept study, a model for teachers' professional development of the mathematical concepts (Davis & Renert, 2014). The paper ends by providing the potential of practicing complexity theory in mathematics class.

Keywords: Complexity theory; Concept Study; Mathematics Class; Mathematics-for-teaching

1. Introduction

1.1. Context

This paper describes the ways that complexity theory can be used in math class to encourage students' participation in learning mathematical concepts. The paper illustrates the theory based on secondary sources of data, and this theory is important because it allows the collective learning of the mathematical concepts in the class. In doing so, it opens multiple ways of interpreting the concepts and a variety of ways to understand the concepts among learners in the class.

1.2. Description of complexity theory by relating it to mathematics education

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The Complexity theory has been foremost among the provoking theories, not only in the field of science but also in mathematics, sociology, psychology, and philosophy. This theory came into the teaching and learning process due to the shift from the pedagogy in which the information is transmitted from point A to point B to the pedagogy whereby point A and point B are interconnected, interrelated and interdependent as a distributed network. This theory emphasizes that knowledge is dynamic and emergent, it allows shared participation in a collective classroom (Doll, 1993; Newell, 2008; Davis & Sumara, 2006; Davis & Simmt, 2006).

The complexity theory is among modes of curriculum inquiries that give both learners and teachers the power in the teaching and learning process. Using this theory in a learning context, ideas from every individual are respected, and everyone is open-minded to listen to each other and articulate the ideas into meaningful learning. Social collective is the major key when using this mode of curriculum inquiry in the classroom, as pointed out very early by Aristotle, “the whole is greater than the sum of its parts.” Thus, using complexity theory in mathematics is important as the mode is becoming very useful for mathematics teachers and mathematics educators in the classroom for enhancing individual student’s participation in learning mathematical concepts. As well, it is useful in research to gain deep insight into mathematics-for-teaching at school, college, and university levels. Mathematics-for-teaching is:

> a way of being with mathematics knowledge that enables a teacher to structure learning situations, interpret student actions mindfully, and respond flexibly, in ways that enable learners to extend understandings and expand the range of their interpretive possibilities through access to powerful connections and appropriate practice (Davis & Renert, 2014, p. 4).

As such, as a teacher, having mathematics for teaching, the classroom under the guidance of the teacher becomes socially interconnected, interrelated and interdependent, which in turn the class might bring the emergence of ideas and self-organization among participants in the teaching and learning environment.

In mathematics education, the complexity theory was pioneered by Dennis Sumara and Brent Davis. Dennis Sumara was working in English language art, while Brent Davis was researching mathematics for teaching and learning. Together they intensively investigated complexity theory in their own subject areas and across the school curriculum. Currently, Elaine Simmt is working in this area in the department of secondary education at the University of Alberta, whereby Professor Simmt gives more emphasis of practicing complexity theory in the class through concept study — a model for teachers’ professional development of the mathematical concepts. The three curriculum scholars mentioned above are all Canadian researchers who continue to work in the complexity theory.

The complexity theory emerges from science when scientists were investigating the behavior of different objects under study. The studied behavior of objects was not predictable, as a result, scientists could come up with unexpected results/emergence (Davis & Simmt, 2003, 2006). As such, complexity science can be defined as the "way of investigating and discussing a class of phenomena from many different disciplines that are resistant to being understood through reductionist analysis" (Newell, 2008, p. 5). The phenomena and the complex objects are incompletely understood, and they might attribute the emergence and self-organization. As such, it is important to differentiate a complex system from a complicated system. The three paragraphs below provide the differences between these two terms.

Complex system: It is important to know the "complex system" and know how this term is distinguished from "complicated system". In a complex system, the object is not fixed, the interactions of components are not fixed, they are non-linear, and they are not clearly defined, and components of the complex system are subjected to co-adaptation allowing the emergence of patterns. But, the complicated system has many parts which are fixed, and the relationship between those parts are clearly defined as we can see in this video link:
(http://www.bing.com/videos/search?q=chaos+and+complexity+theories+you+tube&FORM=VIRE7#view=detail&mid=5A5C7D0EEDB3C7202F065A5C7D0EEDB3C7202F06)

Examples of complicated systems include a clock and motor vehicle, while all living organisms are an example of a complex system. As such, complicated system is mechanical while the complex system is associated with the principle of biology and evolution. Davis and Sumara (2006) give a clear distinction between a complex system and complicated system as outlined below:

> …although a complicated system might have many components, the relationship between those parts is fixed and clearly defined. If it were carefully dismantled and reassembled, the system would work in exactly the same way. However, there exist some forms that cannot be dismantled and reassembled, whose characters are destroyed when the relationships among components are broken. Within these sorts of complex systems, interactions of components are not fixed and clearly defined, but are subject to on-going co-adaptations (Ibid, p. 11).

In a classroom context, the class is a complex system, consisting of different students having different learning attributes, including culture, gender, language, ways of knowing, and experiences. As such, in the teaching and learning process, listening to everyone in the learning is the key factor for every individual to articulate the ideas of others, and appreciate the individual differences. Listening to one another is not always easy as it involves evaluative, interpretive and hermeneutic listening at the same time and space. As such, Davis and Renert (2014) call this kind of listening "three co-implicated modes of listening" (p. 86). These three models of listening are described in the paragraph below.

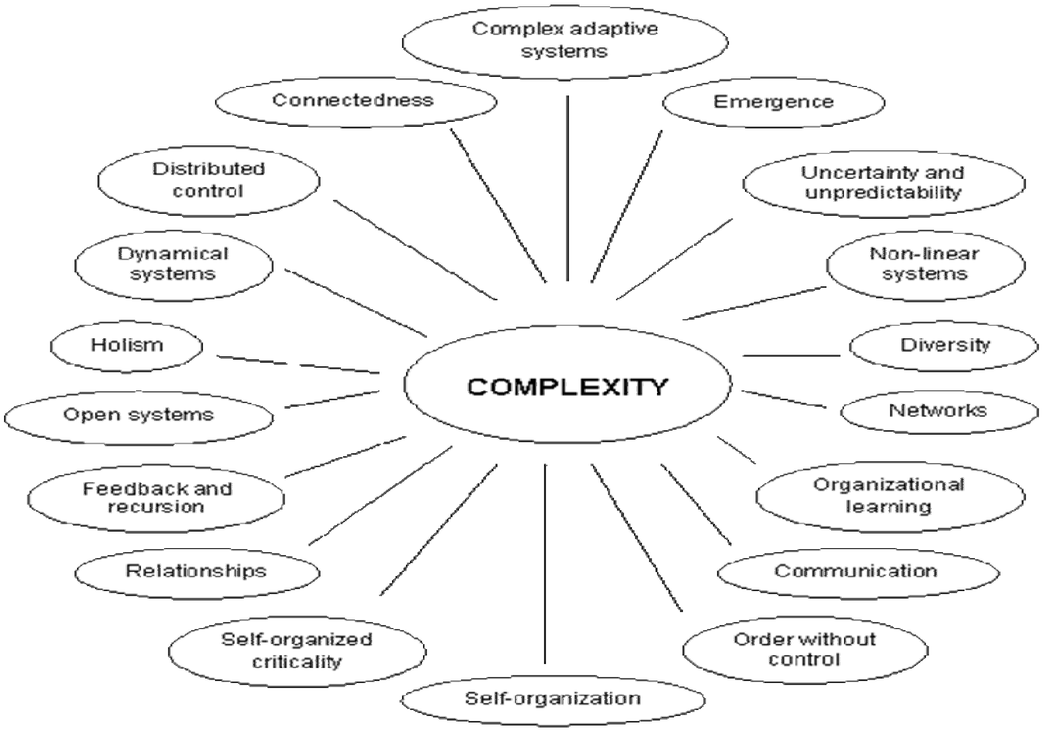
Evaluative listening involves seeking answers, evaluating correctness, and orienting to established knowledge. Interpretive listening involves seeking interpretations, making sense of understanding, and orienting to where the learner is in the moment. And hermeneutic listening involves seeking variation, participating in meaning-making, and orienting by not yet articulated possibilities (Davis & Renert, 2014). Thus, through listening to each other in the classroom context in a complex system, learning might become emergent, self-organized, self-maintained and transformed (Doll, 1993).

Complexity thinking is seen when practicing the complexity theory in a class. We need to realize that the theory emphasizes the complexity of thinking among participants. As such, we need to know, what does complexity thinking mean? To what extent do we think in a complex system? Davis and Sumara (2006) define complexity thinking as, "a way of thinking and acting" (p. 18). While reflecting on Davis and Sumara's (2006) definition of complexity thinking, we can notice that people think and act differently on a certain concept or idea. As such, it is important to appreciate the individual differences and value the contributions of every individual learner. In doing so, we avoid rupture that might occur during teaching and learning process and continue keeping in mind that the complexity theory emphasizes social collective rather than an individual in the learning enterprise.

Complexity theory is originated from physics, chemistry, cybernetics, information science and systems theory. The theory can be categorized into two as hard complexity theory and soft complexity theory. Hard complexity theory is originated in physics, which focuses on analytic analysis that concern with the nature of reality. While soft complexity theory is originated in biological science, which is more interpretive aiming to describe living and social systems. As such, Davis and Sumara (2006) define the "complexity thinking" lying somewhere in between hard and soft complexity theories. Both categories of complexity theory are important in mathematics learning and teaching.

1.3. Attributes of complexity theory which are necessary for organizing the class to encourage students' participation in learning of the mathematical concepts

The elements of complexity theory can be articulated in mathematics teaching and learning classroom, and in mathematics education research in different ways, including through organizing the class for researching and teachers' professional development of the mathematical concepts using concept study model. The elements of complexity theory as pointed out in the work of Lewin (1993) and Morrison (2002) include self-organization, emergent, decentralized control, connectedness, internal diversity, complex adaptive system, networks, non-linear systems, and communication as we can see in the figure below:



Retrieved from: http://cw.routledge.com/textbooks/9780415368780/A/ch1doc.asp

Each of the attributes of the complexity theory can be applied in mathematics class during teaching and learning process to enhance students' participation in learning the concepts. The section below illustrates how these attributes can be used in mathematics class under the lens of concept study during teaching and learning process.

2. Illustrations of the ways that the attributes of complexity theory can be practiced in mathematics class to encourage collective learning of the concepts

The Connectedness: This attribute can be practiced in the class through allowing students to connect one mathematical idea or concept to another, to give deep understanding of the mathematical concepts in terms of realization and landscape. The connectedness of concepts can be attained through providing feedback, recursion and perturbation. For instance, the concept of *pi* in geometry is connected with finding the circumference and area of a circle. Also, this attribute can be practiced in the class by providing open questions for neighbors to discuss in every class meeting; for instance, asking the question for discussion, "what is pi? (Think, pair and share)". Doing it this way, students become connected to each other all the time throughout the course of study.

Complex adaptive system: In teaching, this attribute can be articulated in the class in different ways, including adapting the teaching environment, availability of resources, every individual student contributes ideas, individual expressions of each students, and ability to listen and understand the ideas of every individual student. This adaptation can help to understand well the teaching and learning environment of my class and students' individual differences.

Emergent: In teaching, this attribute can be practiced in different ways, including allowing students to discuss the concept through asking open questions for discussion, such as what is multiplication? The question like this creates a big space for students to think on the ideas and come up with many different meanings/concepts related with the concept of multiplication. Through a continuous discussion on the concept, emergent ideas might come up from the students in the classroom, as learning becomes accessible to every type of learner. This practice provides an open learning because students are more engaged in learning the mathematical concepts in the class.

Uncertainty and unpredictability: In teaching, we know that the learning outcome is unpredictable. As such, we cannot focus on managing time; we focus on appreciating the ideas coming from each individual student on a certain concept. This way of knowing creates more space for students to contribute ideas and challenge themselves critically on the ideas. Students also might give ideas that can improve the concepts, and the larger curriculum.

Non-linear system: In teaching, we know that the ideas/concepts come from any of the participants. As such, a teacher needs to create the room for students' learning rather than being the source of knowledge, but a facilitator. Practicing this way of teaching, the contributions of ideas from the students becomes more random and less fixed contributions from any participants in the class.

Diversity: In teaching, this attribute works well in the class having many students—large classes. Many students in the class help to build social collective among the class members. Also, complexity model is student centred and not teacher centred, so the more the number of students in the class, the more social collective might be attained, and eventually the more concepts or ideas are articulated in the class. The perspective is that mathematics large class can be interpreted as a class with 60 students above, and a small class might be 40 students below. As such, there are many generated mathematical ideas about the concept among students; complexity theory can still guide teaching and learning in mathematics classroom.

Networks: In teaching, this attribute can be ensured in the class in different ways, including having a distributed network among students themselves, and a teacher and the students, as interrelated, interconnected and interdependent. This network can be attained through giving assignments to students to work in groups, and thereafter presenting in the class, providing feedback to the students, and inviting other teachers (staff) to participate in the class. Also, students can be sent to the community outside the school or university for data collection. In doing so, this practice can help students to build more networking beyond their school/university learning environment.

Self-organization: In teaching, this attribute can be practiced in the class in multiple ways, including through preparing the lesson (course outline) early and give the readings to the students two or four weeks before the class. This practice helps students to be self-organized for the lessons, which in turn brings organizational learning.

Relationships and communication: In teaching, this attribute can be articulated in the class through building good relationship with the students in different ways, including teachers respecting themselves the way of dressing professionally, ways of interacting with the students, ways of talking and listening, and ways of giving feedback to the students. Also, informing the students when a teacher fails to attend in the class with good reasons such as being sick, and other issues that are common to human beings. Furthermore, making sure that the students communicate to each other in the class in meaningful ways to allow learning to take place. Finally, students should be free to inform teachers if they might miss class as well.

Feedback: As a teacher, providing feedback to the students a few days after receiving the submitted assignment(s) is important for students' ongoing learning. Also, in the classroom, teachers need to provide feedback such as comments and suggestions at the end of the class to provide clarity of the concepts or ideas contributed by the students that seem to be unclear-misconception(s).

Open systems: In teaching, the discussion of the concepts should be open to every student in the class. The idea of every individual student should be valued and respected. As such, teachers need to discourage creating the gap of knowers and learners, to raise the openness of the classroom so that as many students as possible can contribute ideas on a certain concept.

Complexity theory has implication in research; especially when conducting research which involves human beings with different individual differences. As such, the complexity theory enables us when conducting researches to be effective and trustworthy while collecting data through involving diversity of people, emphasizing networks among participants, recognizing individual differences, and asking participants open questions that might bring the emergent of ideas/concepts such as, "what is addition? (think, pair and share)." Also, the theory helps us to be self-organized focusing on the research question(s), appropriate instruments for data collection, and nature of the participants in the research study that are interviewed in exploring the concepts/ideas on the asked research questions.

Also, in research, the complexity theory opens our mind in conducting research in mathematics education through different ways, including using concept study. Concept study is "a participatory methodology through which teachers interrogate and elaborate their mathematics" (Davis & Renert, 2014, p. 35). Concept study involves concept analysis and lesson study (Davis & Renert, 2014). Concept analysis in a concept study focuses on a well-known collaborative structure that, "teachers engage in to improve the quality of their teaching and enrich students' learning experiences" (Fernandez &

Yoshida, 2004, p. 4). Lesson study is “oriented towards new pedagogical possibilities through participatory, collective, and ongoing engagement” (Davis & Renert, 2014, p. 39). The concept study is more focused on the actual mathematics content of teaching through allowing teachers as a community of experts to share ideas on a certain concept in a collective way. As such, through inclusion of diversity of participants in the concept study creates a complex system that might open up emergent possibilities. Concept study can be seen in the work of mathematics educators, including Davis and Simmt (2003, 2006), and Davis and Sumara (2006). For instance, focusing on Davis and Simmt (2006), they conducted a concept study on multiplication to in-service mathematics teachers and educators using complexity science as a framework of interpretation. Davis and Simmt (2006) started asking the question, “what is multiplication?” Many ideas and different meanings of multiplication emerged from the participants, including repeated addition; equal grouping; number-line hopping; sequential folding; many layered (literal meaning of ‘multiply’); ratios and rates; array-generating; area-producing; dimension-changing; number-line stretching or compressing (Davis & Simmt, 2006, p. 301).

Complexity theory as a model for teaching and learning, strengthens and enhances our curricula and pedagogies practices in mathematics class; this elaboration is through using the concept studies with teachers in a collective way; and as a result, we obtain the quality of knowledge for teaching that enhances students’ mathematical understanding. As such, reflecting in large class context, it can be seen the need to change from lecturing; the teacher being only the source of knowledge to students’ centred learning through using a concept study in the mathematics classroom. This practice can bring a big shift in teaching to meet the goal of working towards teachers’ teaching practice in the class and the students’ needs as well.

Using complexity theory as a model of inquiry requires a mathematics teacher first to raise awareness to students in the class to be familiar with the implications of complexity theory in the mathematics class. Also, making sure that, the students understand the meaning of concept study in mathematics, because of using concept study which is grounded in complexity theory. For raising awareness students need to know “What is a concept study?” “How the concept study is conducted.” “What is the purpose of the concept study?”

However, there are challenges of using concept study which is grounded in the complexity theory, such as, it demands more time, and needs to build a strong relationship among students and teachers. As such, when teaching, teachers should make sure they build this learning community in the mathematics classroom by having a flexible time to allow students to think critically on a concept.

In teaching through using concept study in a complex system, the mode of assessment should focus on what extent students gain new insights, embody patience in the learning process, demonstrate an inquiry-based orientation to learning, and engage in other activities that measure students’ learning achievements.

3. Conclusion

This paper ends by providing the potential of practicing complexity theory in mathematics class. Complexity theory as a model of inquiry is potential in mathematics class for organizing the class to allow individual and collective understandings of the mathematical concepts. In doing so, it is important to realize the aspects of the theory which are associated with dynamic and collective learning community, and the aspects of the theory that must be well integrated in the mathematics teaching and learning process. The aspects include interpreting idiosyncratic individual and group students' responses, prompting multiple interpretations among students in the class, tracing misinterpretations and eliminate them, and structuring rich learning experiences among learners in the class. Also, the practice of complexity theory can stimulate the influential change to curriculum and pedagogical practices in the mathematics class by encouraging students' participation in learning mathematical concepts as both individual and collective learners. In doing so, the theory opens many teaching and learning possibilities in mathematics classroom during teaching and learning process. The possibilities include: new mathematical ideas, images and language are introduced into the conversations; emergent mathematical concepts exist in the class; classroom collective learning of the mathematical concepts exist; and self-organization and the unexpected events occur in the class based on learning the mathematical concepts during class discussions.

References

Davis, B., & Renert, M. (2014). *The math teachers know: Profound understanding of emergent mathematics.* New York, NY: Routledge.

Davis, B. & Simmt, E. (2003). Understanding learning systems: mathematics education and complexity science. *Journal for Research in Mathematics Education 34*(2), 137-167.

Davis, B. & Simmt, E. (2006). Mathematics-for-teaching: an ongoing investigation of the mathematics that teachers (need to) know. *Educational Studies in Mathematics*, 61, 293-319. Retrieved from http://www.jstor.org/discover/10.2307/25472073?sid=21105242935431&uid=3737720&uid=4&uid=2&uid=3739392

Davis, B., & Sumara, D. (2006). Complexity and education: Inquiries into learning, teaching, and research. Mahwah, NJ: Lawrence Erlbaum.

Doll, W. E. (1993). *A post-modern perspective on curriculum.* New York: Teachers College Press.

Fernandez, C., & Yoshida, M. (2004). *Lesson study: a Japanese approach to improving mathematics teaching and learning.* Mahwah, NJ: Erlbaum.

Lewin, R. (1993). Complexity: life on the edge. London: Phoenix.

Morrison, B. (2002*). School leadership and complexity theory.* London: RoutledgeFarmer.

Newell, C. (2008). The class as a learning entity (complex adaptive system): An idea from complexity science and educational research. *Simon Fraser University Educational Review 2*(1), 5-17.