

**IV INTERNATIONAL BIENNIAL SYMPOSIUM
“COMPLEXITY 2011 – FOR A SUSTAINABLE DEVELOPMENT”**

EDUCATION, COMPLEXITY, INTERDISCIPLINARITY, TRANSDISCIPLINARITY

June 2011

UNIVERSITY OF CAMAGUEY CUBA

**MODELING AND EDUCATIONAL SIMULATION AS A BASIS FOR SUSTAINABLE
DEVELOPMENT**

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ABSTRACT

Sustainable development is the result of research and the application of science and technology in complex, uncertain and changing situations. To accomplish its effectiveness, it is necessary to establish such processes in education with an epistemological orientation on the same line; this is, to be understood as a complex system that allows a prospective and possible vision, in line with reality.

Education systems are dynamic systems of increasing complexity that develop within unstable contexts of constant change. These are characterized by nonlinear interactions between multiple actors at different levels and scales of inter- and trans- disciplinary type, that generate the emergence of persistent patterns with changing components (self-organized, adaptive, self-recursive and with catastrophic behavior), resulting in the generation of possible scenarios that affect collective behavior. In other words, the education systems are developed in a continuous dynamic of order/disorder, with a permanent structural change that makes them unpredictable and far from any causal explanation.

To manage unstable contexts of probable sustainability, education requires a new rationale, a new method of heuristic and metaheuristic type that does not focus on the reality that is known and that is predetermined by inductive or deductive ways with rigid and statistical processes. Instead, to manage these unstable contexts, education should be built on the interaction of variables and chaotic dynamics, through processes of modeling and simulation, in a work of synthesis (rather than in an analysis with nonlinear results) where it can be appreciated the dynamics of the levels and the generation of increasing complexity.

KEYWORDS

Sustainable development, education, modeling and simulation, complex systems.

INTRODUCTION

Given the global sustainability crisis that humanity is facing while risking the resource management, the coexistence, and survival of the planet, it is urgently needed to define and implement educational strategies that enable sustainable development and that are consistent with the complexity of reality. Based on the foregoing, the thesis proposed in this paper is that, to achieve sustainable development in the XXI century, it must be implemented processes of higher education that integrate technologies such nonlinear heuristic and metaheuristics through processes of modeling and simulation in a shaft of transdisciplinarity in order to develop the necessary work skills for managing sustainable development.

EDUCATION AND SUSTAINABILITY

The way in which reality, knowledge, and science has been conceived, under economic and development prospects, have led to a global crisis at the social, ethical, economic, political, environmental and energy level, that has not yet responded to interventions and forecasting-linear planning- and reductionist strategies of modern paradigm, putting at risk the survival and sustainability of the planet. It therefore requires a new look, a new understanding of reality that allows the construction and implementation of a paradigm that meets the needs of humanity through strategies to achieve sustainable development.

The reality on which is based the postmodernism is based on uncertainty, instability, openness, dialogue, constant change, plurality, transdisciplinarity and a new rationality framed by different logics. In that sense, are these pillars on which the new science must be built to guide the development and new methodologies to address the reality and not, the certainties that tried to show modernism and its rule of reason linear, fragmented and reductionist. In this context and orientation, the complexity has emerged as a science that tries to explain the world in a scientific way through the study of nonlinear dynamic systems and emergent phenomena processes supported by simulation [1].

Although different strategies have been developed by the global community to achieve sustainability while meeting present needs without compromising the needs of the future, - this is taking into account ecological, economic and social factors, [2] and even involving the fourth pillar of cultural and biological diversity variable-, [3] it has not been able yet to

clarify the concept of sustainable development in a collective manner, and although it is clear that education as a motivator and as a reflection of society is the central point and foundation to achieve sustainable development, there are still many gaps in this regard and is in that line that the collective work should be guided.

In fact the UN in collaboration with the World Bank (WB), the International Union for Conservation of Nature (IUCN), the Organization of American States (OAS) and the Organization for Economic Cooperation and Development (OECD) have oriented education for sustainable future on a transdisciplinary vision for concerted action. Also, the United Nations proclaimed the decade for education for sustainability (2005-2014) stressing that, education is an indispensable element to achieve sustainable development, [4] situation that has been energized by various institutions such as the Organization of Ibero-American States for Education, Scientific and Cultural Organization which highlights the need for education "to pay systematic attention to the world situation in order to provide a correct perception of problems" [5].

However, the educational theories have been based on the consistent, the order, the predictable and on linear planning; ignoring that reality is uncertain and changing. This generates a significant gap between the theory and what happens in reality. Therefore, it is required for the epistemology of social science (which is involved in education) to be based on the basis of chaotic and uncertain relationships while focusing its attention on the interactions and patterns of emergencies which, besides being unexpected, occur at different levels of systems. Otherwise, education will not be effective to boost sustainable development.

Therefore, in order for educational processes to impact on sustainability, it is from the same state and institutional policies that renewal strategies of epistemological, pedagogical and curriculum processes must be involved, while including trainer education programs towards an open and plural mind and under, the frame of an active participation within the academic community. Special attention must be paid, in this context, to higher education (central point of this paper) for being the link between: academia, research and workforce and which, at the same time, requires specific skill training by the student to effectively guide the effort towards sustainable development from different disciplines. University programs therefore require to be flexible, dynamic and open to dialogue between different sciences in order to, on a transdisciplinary axis, foster innovative practices that enable sustainable development effectiveness based on the understanding

of a contemporary paradigm that explains the complexity of reality and allow the construction of knowledge and science through methodologies that involve technological development in the same line. In this regard, it is worth to highlight the ninth principle of the Rio Declaration, which emphasizes the need for states to "cooperate in strengthening their capacity to achieve sustainable development by improving scientific understanding through exchanges of knowledge science and technology, and enhancing the development, adaptation, dissemination and transfer of technologies, including, new and innovative technologies "[6]. In other words, it is required that, from a new worldview and a new epistemological orientation in line with reality, innovative practices in higher education to be encouraged to truly impact sustainable development and do not stay simply in the speech.

Historically, there has been a gap between educational knowledge and discipline, which delays pedagogical ideas regarding social, political, cultural and economic changes [7]. Therefore, higher education must be integrated into the development of the discipline, into the needs of complexity of society and into the current perception of reality, while assuming a scientific nature not only in terms of theoretical and epistemological autonomy [8] but in terms of its practical application to solve real life problems that integrate the scientific and technological development. Science, research and technology must, therefore, go hand in hand with education, otherwise this will not fulfill its role as a driver in society and thus, as a driver of sustainability.

In this regard, and based on the concept that contemporary scientific models are heuristic (rely on other logics to create new ways) and use additional tools such as simulation to solve problems, education must be able to translate the scientific thought into processes of creation within the context of the students [9]. To achieve this, education and teaching-learning processes must transcend the positivistic behavioral-linear approaches of empirical-analytical type, and the social critical or historical hermeneutic methodologies to appropriate contemporary methodologies that conceive reality as a complex system characterized by chaos, interaction, uncertainty, randomness and emergencies that are beyond any prediction and traditional scheme [10]. And that, is in this context, where modeling and simulation come to play a leading role to understand realities and to propose solutions.

Models in general, serve to capture the essence of reality intended to be studied, help to interpret the world and facilitate processes of inference and knowledge transfer to different

situations [11]. However, they are rigid and schematic representations of reality unlike dynamic models of the sciences of complexity (resulted of the simulation and modeling) [12]. The latest, have the advantage over the formal logical deductive inferences of traditional science (which are not analytically tractable for being at the edge of chaos and that infinitesimal precision is impossible to be given with other techniques) because they can work on complex phenomena and their emergencies. Furthermore, they are able to integrate different levels in the same computational model, as in the case of neural networks or social systems. This allows an understanding of the complexity and its relation with the possible through the integration of thought, reality and virtuality while constantly opening new epistemological horizons [13]

The basic components that make up a system for sustainable development are multiple and involve human, economic, social, energy, cultural, environmental education, biological and ethical elements among others... these are specific and changing variables for each local context, however they are part of a complex system, to the extent that they present an ongoing interaction, they are at different levels of action and have self-organizing processes, nonlinear feedback loops and adaptation to the environment. The permanent and dynamic interaction of all the basic components of the system cause new or emerging situations that may not otherwise be provided with pre-structured schedules, explaining the gap that occurs in reality between what is expected and what actually occurs.

In fact, these emerging situations or macroscopic patterns resultant, are impossible to be inferred mathematically or by linear statistical methods because of its level of complexity (emergent phenomena can't be deduced from the behavior of components or by the rules of interaction between them, given that they emerge from the interaction) [14]. However, sciences of complexity across different tools and techniques can make inferences on algorithmic processes inaccessible to the human mind. What is evident in social practices is that, they have wanted to resolve the problems of sustainability without taking into account the complexity of the linear projections, which could be analogous to leave it to randomness.

These modeling and simulation systems can be possible thanks to the use of computers, which are inference machines that can process algorithm processes at high speeds and allow humankind to study the complexity of the reality beyond the current limits of mathematics. The result is a potentially more realistic model with formal rigor as the traditional ones. These computing machines have a huge number of recombine and

convertible binary states expressed in one program, that enable the reproduction of the processes of a problem while giving the chance to explore different alternatives and recreate various scenarios [15], allowing to work with algorithmic and computational problems. However, it is important to clarify that the work with modeling and simulation, further than being a computer programming task, is grounded in “the knowledge, study and work with complex nonlinear systems with the help of the computer” (..) “In this regard, simulation and modeling demands a conceptual and / or previous theoretical work.” [16] It is important to highlight that this previous theoretical abstraction, by being the essence of what is wanted to be modeled and simulated, deserves to researchers to have an epistemic clarity because, despite its magnitude and potential, it is just a tool after all.

Under this approach, modeling and simulation are used "when we seek to understand and explain fundamental processes; when we want a phenomenon or system to behave as we want / wish; when we get to see emergencies, dynamics, processes and other items that we do not usually understand; that is, precisely, what is outside of simulation and modeling "[17] and also, they facilitate the opening up to truly creative and innovative processes, by making it possible to understand "not so much life as we know it but in the way it could be possible" [18], a vision that should guide work with sustainable development.

Based on the foregoing, the idea is that sustainable development is a fundamental part of university policies and their curricula on the basis of a new epistemological orientation. By training teachers and students in the sciences of complexity, and by creating, in the same line, research groups in different academic programs, students will be formed to manage unstable and dynamic environments through the critical analysis of real situations with the help of computers (its modeling and simulation), not only through prescriptive and ethical concepts but by developing significant learning processes aimed to understand and intervene reality. If this process is carried out continuously and systematically in the academic community, it is through the interaction of different areas that culture of sustainable development management can be created. This does not require, as outlined below, to all students to master the techniques of modeling but to them, to be part of transdisciplinary teams that focus on a common problem.

To outline the dynamics of the educational approach, it is important to take into account the essential elements involved in the process of modeling and simulation: in general, computational models are built on the basis of an expert who knows the real system, a modeler on charge of the program processing and computer programming that meets the

formal model. What previously was performed by a mathematician, is now executed by the computer (given the complexity) in the stages of abstraction, design, coding, inference, analysis, interpretation and application [19]

Modeling and simulation from the education and training approach, requires a sharing scenario where various experts are involved, including teacher(s) and research students from different disciplines - who already know the real system, its operation and the variables to be modeled-. This is, to have a common problem to work on, under a transdisciplinary true sense. An approach that goes beyond the subdivision and fragmentation of knowledge, by understanding the complexity of the real world its relationships and interconnections and which, transcends its own disciplines while focusing around a common problem with a team that shares an epistemic route through a methodology, integrating diverse perspectives, approaches and principles. [20]

These expert researchers must make a conceptual or theoretical framework of the relevant aspects of the real situation to be simulated by defining shared objectives, by identifying key components and possible interactions and by creating a conceptual and graphical synthesis that allows a collective construction and a common language with programmers. At this point it is important that an emerging dynamic surfaces within the group (from a shared reality and objective, each one individually works on his conceptualization, which later will be shared, and from there, different views and understandings of a particular situation will appear, allowing a group pattern to emerge). This process deserves training in essential skills such as teamwork, social and emotional intelligence, assertive communication and active listening among others.

Within the team, should also be modelers or programming experts in nonlinear dynamics of different disciplines, according to the initial conceptualization and abstraction to the objectives established, who will determine which is the most appropriate technique (cellular automata, agent-based simulation, genetic algorithms, fractal geometry etc), and according to it, to design, analyze and codify the models that meet the objectives. Just as in the previous phase, it is required of a dynamic with a high degree of teamwork to ensure that specifications are consistent with the experts in charge of modeling. It is important for the modeling process to be consistent with the theoretical conceptualization; otherwise there is a risk that the process will take another route. It is fundamental to highlight that the modeler or programmer should understand the situation he is working on and to provide from his perspective to achieve a sense of collective construction.

Finally, it ends with the inference process, analysis, interpretation and application - according to the referents of the real system and the meaning and understanding acquired in consensus within the team through feedback processes and continuing new cycles-. The result of this dynamic must be socialized and integrated with various stakeholders not only from academia but also with government, industry, international agencies and other decision makers called to face the challenge of sustainable development for humanity in XXI century.

CONCLUSIONS

Higher education as a foundation for sustainable development must be promoted through the science of complexity in modeling and simulation processes that reflect the complexity of reality.

Modeling and simulation in higher education are tools that optimize transdisciplinarity which is the basis for sustainable development.

Modeling and simulation in higher education develop work skills for future professionals to address issues of sustainability.

Sustainable development urgently requires a paradigm shift in the academic community and in education.

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