Project Number: 2020-1-SE01-KA203-077872

Erasmus + Cooperation for innovation and the exchange of good practice
KA2 - Strategic Partnerships for Higher Education
Project Number: 2020-1-SE01-KA203-077872

REPORT ON LITERATURE REVIEW ON THE THEORY OF COMPLEX SYSTEMS APPLIED TO:

ENVIRONMENTAL STUDIES

DEVELOPMENT STUDIES

MEDIA TECHNOLOGY (COMPUTER SCIENCE AND MATHEMATICS)

Tomas Kjellqvist, Ann Mutvei, Martin Jonsson
Södertörn University
Huddinge, Sweden

tomas.kjellqvist@sh.se, ann.mutvei@sh.se

Co-funded by the Erasmus+ Programme of the European Union

The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

LEARNING ABOUT COMPLEXITY IN COUPLED SYSTEMS FOR SYSTEMS THINKING ON SUSTAINABLE DEVELOPMENT

ABSTRACT

Managing complexity related to Sustainable Development requires knowledge, understanding and skills on coupled systems. This term often refers to socio-ecological or socio-technological systems, where system understandings from social sciences need to mix with or be confronted by understandings from natural science and from engineering. This report takes its points of departure from comprehensions in multidisciplinary education programs at the School of Natural Science, Environment and Technology. The literature review behind the report has covered various multi- or trans-disciplinary approaches to complexity with relevance for systems thinking. The findings are that systems thinking on coupled systems is not a unified conceptual framework. Various competing schools have emerged during the history of concerns for environment and development. In this plethora it is possible to read in both complementarities and contradictions regarding epistemologies and ontologies of complexity. In learning situations involving systems thinking, the framing of the system requires a conscious selection of possible approaches. The challenge for university teachers is to approach these epistemological and ontological in a pedagogical manner when setting up learning situations for students and for university partners in transdisciplinary endeavors.

1. Introduction

Higher education on environment and development shares a history with the UN conferences and common debates on the topics. The term sustainable development has emerged in a co-creation between the academic community and UN bodies and their national members to combine two opposing phenomena. Much of the scientific literature on environment and development aims to find ways of understanding about the complex interactions between human activities and events in the environment. One of the seminal attempts to do this with a systems dynamic analysis was presented in the book "Limits to growth" in 1972, same year as the first UN conference on environment and development (Meadows 2004). The approach in the book was criticized for being too simplistic in the choice of system components and interactions, but at the same time it was celebrated (even by the critics) for illuminating the challenges to developmental approaches lacking environmental concerns. The system dynamic analysis has since been complemented with a high variety of approaches to complexity and to systems thinking relevant for coupled systems. In this report we will draw some conclusions on how this variety can be used in setting up learning opportunities for systems thinking.

2. Results Achieved

To learn about systems thinking on complexity for Sustainable Development requires students to get familiar with thinking on coupled systems. The literature review thus came to focus on articles and books related to socio-ecological and socio-technological systems. It soon became clear that many authors, including teachers at the School of Natural science, environment and technology at Södertörn University did study complexity, but not with these concepts. The review was then broadened to cover also other approaches to the nature/society dilemma, such as political ecology. Hence, we discovered complementarities as well as contradictions between the approaches, often on the levels of epistemologies and ontologies. Partly this could be understood as emerging from a common concern for environmental issues but different ways of social and natural science to approach the couplings. However, it is also possible to discern conflicts that relate to the analysis of how politics and analysis of power relations influence the couplings. When setting up learning situations we found it important to take account of these various approaches to find pragmatic ways of using them to understand the complexity of complexity. The different approaches can be used in the discussion of how to frame and populate the complex system of interest to the learning situation.

Co-funded by the Erasmus+ Programme of the European Union

The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

During the review our attention was drawn to the transdisciplinary approaches advocated for sustainability studies. We realized that learning tools need to be developed in such a way that it can be used both in classroom for fresh students, but also for working students engaging in continuing education and in various forms of action research engaging academic staff with community members. On finding was that many of the approaches used for systems thinking in actions research could also be applied in classroom situations.

In the following presentation of results, we aim to illuminate the need to introduce systems thinking in a progression with increasing complexity.

2.1 Complexity Science

The complexity in this literature review is related to environment and development issues, in academic studies as well as in the practice of development aid offices, agencies for environmental protection and in companies with sustainability agendas. The various problems and dilemmas within their work tasks are often described as "wicked problems" with no linear cause and effect chains and with a high degree of uncertainty regarding possible impact of interventions. The reviewed literature links to the practice that student will engage in within such bodies, and the diversity of system thinking that can be applied to their learning experiences. The review was undertaken with two modalities of learning experiences for systems thinking in mind. The first is geared towards setting up specific course modules for systems thinking and the other is applying systems thinking as injections to existing courses.

The most important feature of systems thinking is that "systems" are a focal device (Lundvall 2016) and that framing of a selected "system of interest" is a challenging exercise (Ison 2017). In other word, systems do not exist in the real world, they are conceptual tools that we can use to describe and grasp complex situations. Training students for system thinking practices could start from the basic description of systems continuing with problematization of the system features such as borders, element and interactions. With a focus on application of systems thinking to sustainable development and to transdisciplinarity, most of these concepts require a contextualized definition and an alignment to the chosen theoretical approaches

2.2 Sustainable development

Taking the 2030 Agenda as a point of departure for definitions of Sustainable development is relevant. This agenda summarizes more than 50 years of discussions on environment and development issues, and in its definition of 17 integrated goals it in itself provides some clues as to which elements need to be included in an analysis of a sustainability topic. However, the agenda is written in a generic and abstract language which needs translation to local situations and challenges. In the reviewed literature we found plentiful examples of how this can be addressed.

A course dedicated to systems thinking for sustainable development could be based on articles covering socio-ecological and socio-technological systems. One possible outline would be to follow how these system approaches have developed over time. In short, this history is in itself a history of how systems thinking gets increasingly complex as theories develop and get criticized for their shortcomings. The historical outline could be used as a pedagogical tool to discover systems thinking.

In a brief sketch, it would be interesting to start with the system dynamics applied in the "Limits to growth" from 1972. The model (the LTG-model) applied linked population growth and economic growth to developments in socio-economic sectors related to natural resource use and environmental hazards. The system dynamic model was used to simulate possible scenarios with varying degrees of un-sustainability (even though this word was not used at that time) (Meadows et al 2004).

Understanding the criticism raised against the approach could be a way of learning systems thinking. Part of the critique was against the ***elements selected as part of the system*** model and what elements that other researchers

Co-funded by the Erasmus+ Programme of the European Union
The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

would have liked to see included. This talks directly to the problem of framing the system of interest, where the selection of elements is one important issue.

Another part of the critique was against the type and scope of ***interactions between the elements*** that were assumed in the LTG-model. Critique was raised as technical issues (i.e., how the model equations were formulated) but also at epistemological and ontological levels (Cole et al 1975). In system dynamic models, interactions are thought of as positive or negative feedback loops that balance the system, and when one of them gets the overhand, the system get out of balance. In other and later approaches to systems thinking, there is a great variety of more elaborated ways on how to think about interactions which can be successively introduced to students. When thinking of relations between humans and between humans and non-human entities in the socio-ecological and socio-technological systems it becomes evident that too simplistic descriptions of interactions get insufficient. Recent articles are introducing more philosophical ways of thinking of meshed interactions that are relevant to the complexity dilemmas of sustainable development. Examples can be found in Actor-Network theory and in various interpretations of Deleuze and Guattari´s ideas of Assemblages (Deleuze et al 1984). Many articles in the literature review show that these two schools of thoughts would defend a place in a course on systems thinking for sustainability.

One widely acknowledged benefit of the LTG-model was that its scenarios demonstrated ***counterintutitive emergence***, resulting from minor changes in the variables of the elements and the interactions (Forrester 1971). Emergence is one of the concepts that students need to understand, in the meaning that the system as a whole has features that cannot be explained by the individual elements, but in some cases, not always, by the agglomerated constitution. The nonlinearity of a complex system and the uncertainty are other features that make it hard to predict the outcome. Simulations, as in the LTG-model can give hints to how the non-linearity and the uncertainty may play out. Often it is counterintuitive which is an important lesson when proposing interventions and solutions for sustainability.

The LTG-model is quantitative, based on a huge number of interacting equations. There are many followers to this approach in the systems literature related to sustainability, system dynamic modelling and agent-based modelling as competitors. The quantification has also been criticized and qualitative approaches to system thinking has been suggested. While the qualitative in some cases can be accused of being to static and descriptive, there are numerous examples of how visualizations of a system can be used for scientific analysis, but also as strategic tools in discussions on possible pathways for sustainability. Examples of this can be found in literature related to “political ecology approaches” where the analysis often is based on qualitative (and visual) descriptions of complexity and unexpected interlinkages.

2.3 Inter-disciplinarity and trans-disciplinarity

The choice of environmental studies and development studies point to arrangements of various disciplines to capture the complexity entailed in these themes. The focus in the literature thus came to be on coupled systems such as socio-ecological and socio-technological. Besides the origins in the LTG approach there are various attempts to capture the couplings that may be used in the training. One example is Ostrom´s typology of areas that could be included in socio-ecological studies as system elements (Ostrom 2009). There is also a critique that against that approach for not seriously considering the complexity of relations in the system, a critique that may be amalgamated with other perspectives on how complex systems may be dealt with (Görg et al 2017, Vogt et al 2015).

One critique that could be raised against the LTG-approach is that it does combine issues from various scientific domains, but it does not actually consider the contextual and conflicting debates around the issues within the disciplines. One example is the critique that an underlying assumption in the LTG-approach was neo-malthusian when it came to the assumptions on population growth. In the social sciences of the time neo-malthusianism was contested by the Boserupian approach that emphasized the role of technology and economic growth as negative feedbacks on population growth. According to some of the critics, such dimensions were left out of the model (Cole 1975). Whether true or not, the critique put the finger on a weakness that can be extended also to other system approaches. Often the assumptions made in the system framing do not consider the wider range of debates and discourses around the issues that is integrated in the construction of the system. Truly interdisciplinary approaches need to be more responsive to the internal debates of included disciplines.

Some competing approaches to the complexity of socio-ecological and socio-technological issues have been mentioned above. Articles within political ecology connects phenomena of environmental risks to political science and economic risks. References to systems are common, but often in an abstract way (i.e., the economic system, the political system). Many of the authors are using features from system sciences to describe aspects of the studied phenomena. Flowcharts, blocks describing elements and arrows describing relations are common pictures found in the literature. One of the seminal papers in the school of political ecology used a "chain of explanation" that was clearly systemic in its approach (Blaikie & Brookfield 1987). The main contribution of political ecology is that it introduces power (political, economic, and cultural) in the relations that maintain or drives a system, and thus partly responding to the need to consider relations more seriously when framing systems.

The mere idea of coupled systems can also be criticized. Talking about socio-ecological systems can be perceived as maintaining the gap it is supposed to bridge (West et al 2020). The dilemma is that the different parties in an interdisciplinary collaboration still get stuck within their disciplinary approaches of a clear gap between society and nature.

Philosophical ideas of posthumanism may provide ideas for closing the gap and find new approaches to the complexity. Bruno Latour advice political ecologists to get rid of ecology and instead look for the power ridden relations between humans and more-than-humans (by which he means technological artefacts as well as biological and geological entities) (Latour 2004). His proposal is to use Actor-Network Theory to understand complexity.

Another strand of posthumanist ideas to be inspired from is the idea of assemblages proposed by Gilles Deleuze and Felix Guattari (1984). Assemblages differ from systems as the elements are all considered to have their own agency, regardless of whether they are human actors or non-human entities. They may be gathered in the assemblage by coincidence or by choice, and they may at the same time be members of other assemblages. This way of thinking in systems has attracted political ecologists (Bennet 2010) and geographers (Allen 2011, Anderson & McFairlane 2011)

Through this literature review we came to understand that there are various ways of studying complexity in a systemic way. We also noted a tendency in literature from the last 10 years that the various ways of studying complex systems are becoming more open towards each other, maybe as a reaction to the failure of each school of thought to actually taking full account of what complexity entails.

2.4 Students´ understanding

It is evident from the literature review that understanding complexity is a demanding task for students, but also challenging for teachers who strive to create this understanding among the students. Lecturing on complexity may not result in students managing complexity in tasks and discussions. There is a need to not just show complexity, but to provide tools that forces students to deal with complexity. The literature review showed examples of how tasks can make students wonder about the result they get and from that starting a deeper interrogation.

During the time of this project, we have had the opportunity to test systems thinking in workshop and seminar sessions. One example relates to teaching about health systems in a course on Global Health, where the students do projects on a health intervention of their own choice. The task was to frame the system in which the intervention would occur, starting from actors, relations, and boundaries. After completing the task, the students affirmed that they had got a better understanding of what could make their assumed interventions work or not. The conclusion is that using a simple exercise for systems framing promotes the learning process on complexity.

Co-funded by the Erasmus+ Programme of the European Union

The other example is a task on looking at contradictions and synergies between the Sustainable Development Goals. Students are provided with a cube and an example of a situation; they pick one goal that they think is most relevant for the problem and then uses the cube to think of what goal are opposing, synergetic, dependent, promoting etc. The discussions between students often reveal a complexity, where their disagreement or different interpretations of the goals lead to a deeper understanding of how complex the problem might be. The main message after conducting this exercise in several settings is that the discussion combined with the task to actually glue a goal on one of the cube´s sides also starts students to wonder about complexity and trying out different sets of arguments.

The literature review has inspired us to combine these exercises with theories on system framing, how to look at definitions of actors, agency ad elements in the system, how to look at relations between elements, how to set boundaries and defining the functions of boundaries. This could be done in a specific course on complexity and systems thinking but it could also be integrated in the training that spans over an entire educational program. In the latter case It would be important to think carefully about the progression in learning and how it could be adapted to the different course modules in the program.

2.5 Development of a toolbox

The literature review provided us with several understandings on complexity that could be used in a toolbox. The different ways of thinking quantitatively or qualitatively about systems are complementary, but in many cases the nature of the discipline or topic exclude opportunities to use both perspectives. The toolbox must include possibilities to combine the two ways.

The literature review showed that each of the basic features of a system, elements, interactions, and borders, can be approached with different theoretical understandings. The toolbox needs to demonstrate different perspectives, and the students need to practice with different approaches.

2.6 Discussions with teachers

In our case, discussions with fellow teacher were conducted in parallel with the literature review. Thus, it became evident that complexity issues were included in almost all courses. The teachers welcomed the possibility to include systems thinking in the courses. The discussions showed the need to align tools in the toolbox with the syllabus and the lectures and seminars in the course. This talks to a co-development of the toolbox, which may be a challenge to the view of combining with more generic approaches to the toolbox.

2.7 Discussions with employers

We have also discussed with employers in parallel with the literature review. It is quite clear that the kind of theoretical approaches that is presented in the literature is not of specific use to the hands-on tasks in the companies and agencies interviewed. This talks to a way of learning that allows the students to integrate the theories with practices. The student should be prepared to make decisions on system framing that is based on theoretical assessment, without necessarily having to talk about it in the scientific terms, but present in vernacular language.

References

[1] Allen, J., 2011. Powerful assemblages? Area 43, 154–157. https://doi.org/10.1111/j.1475-4762.2011.01005.x

[2] Anderson, B., McFarlane, C., 2011. Assemblage and geography. Area 43, 124–127. https://doi.org/10.1111/j.1475-4762.2011.01004.x

[3] Bennett, J., (2010). Vibrant matter a political ecology of things. Durham, N.C.: Duke University Press.

[4] Blaikie, Piers M. & Brookfield, Harold Chillingworth (1987). Land degradation and society. New York: Routledge

[5] Cole, H. S. D. (red.) (1975). Models of doom: a critique of The limits to growth. 2. pr. New York:

[6] Deleuze, G., Guattari, Felix. and Massumi, Brian., 1984. Thousand Plateaus: Capitalism and Schizophrenia., Minneapolis, MN: University of Minnesota Press.

Co-funded by the Erasmus+ Programme of the European Union

[7] Forrester, J.W. Counterintuitive behavior of social systems. Theor Decis 2, 109–140 (1971). https://doi.org/10.1007/BF00148991

[8] Görg, C., Brand, U., Haberl, H., Hummel, D., Jahn, T., Liehr, S., 2017. Challenges for Social-Ecological Transformations: Contributions from Social and Political Ecology [WWW Document]. Sustainability. https://doi.org/10.3390/su9071045

[9] Ison, R., 2017. Systems Practice: How to Act In situations of uncertainty and complexity in a climate-change world 2nd ed. 2017, London: Springer London : Imprint: Springer.

[10] Latour, Bruno (2004). Politics of nature: how to bring the sciences into democracy. Cambridge, Mass.: Harvard University Press

[11] Lundvall, B.-Åke, 2016. The Learning Economy and the Economics of Hope, London: Anthem Press.

[12] Meadows, Donella H., Randers, Jorgen & Meadows, Dennis L. (2004). *Limits to growth: the 30-year update*. White River Junction: Chelsea Green Publishing Company

[13] Ostrom, E., 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science 325, 419–422. https://doi.org/10.1126/science.1172133

[14] Vogt, J., Epstein, G., Mincey, S., Fischer, B., McCord, P., 2015. Putting the “E” in SES: unpacking the ecology in the Ostrom social-ecological system framework. Ecology and Society 20. https://doi.org/10.5751/ES-07239-200155

[15] West, S., Haider, L.J., Stålhammar, S., Woroniecki, S., 2020. A relational turn for sustainability science? Relational thinking, leverage points and transformations. Ecosystems and People 16, 304–325. https://doi.org/10.1080/26395916.2020.1814417

Co-funded by the Erasmus+ Programme of the European Union

The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.