Systems Thinking for Sustainable Resource Management in Environmental Management Education

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ABSTRACT: *The sustainability challenge includes a need for new resources. Therefore it is important to show added resource values in sustainability assessments. At the university in Dalarna we use this view, and problem based learning on industrial projects, in environmental management courses. The experiences from those courses, and modelling at Chalmers, indicate how systems thinking can foster a concerted view on business development and environmental priorities. The change in student perceptions indicates that this project work, where the students engage in new mental models, provides a forum where the students can learn to learn.*

Keywords: System Dynamics, Learning, Eco-efficiency, Effectiveness, EMS, LCA, EPS, Powersim

INTRODUCTION

Companies today meet a lot of environmental concern and are exposed to business risks, and Environmental Management is on the rise as a major business priority. Most parties speak in favour of a change to a more sustainable path of development. There are many arguments to reduce environmental impacts, and to motivate and engage people in a better societal development. There is a need for environmental management and improved education. But what can we do? All activities have some effect on the environment and at the same time there can be no life without activity. What "recipes" can we teach? What do the students need to learn?

One step is to show and explain how important the sustainability challenge is. This has been illustrated with thought provoking models, for example in *Limits to Growth*, in the early '70s.

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity. (Meadows et al 1972)

At the same time, it is important to avoid resignation, and, as Meadows et al mentioned as early as in the '70s, it is possible to alter the traditional growth trends and establish a condition of ecological and economic stability that is sustainable far into the future. Since then, models of system dynamics have been used in many more ways, for many different forms of environmental studies, as shown by Ford (1999).

The environmental focus has changed from 'end of pipe' pollution control towards holistic effectiveness. Interdisciplinary goals and visions like Sustainable Development are commonly promoted. Companies aim for reductions in environmental load together with a higher added value, for example as illustrated by the fifty examples in *Factor four: Doubling wealth, halving resource use* (Weizsäcker 1997). A proactive and development oriented view of environmental issues is arising, both in companies and authorities, and also among the general public.

The sustainability challenge relates to various forms of growth. Population and consumption growth are problematic. Still, "growth" is often said to be good for the environment, because increasing per capita income correlates with environmental improvement. Furthermore, "theories about economic growth claim to deal with the genesis of new resources" (Dahmén 1994). Growth may be a way to shift from a base of diminishing returns to one of increasing returns (Arthur 1996). However, "economic growth is not a panacea for environmental quality … What matters is the content of growth" (Arrow *et al* 1995).

The interest in environmental matters and sustainable development ought to provide a competitive advantage for eco-efficient businesses. However, the market mechanism tends to favour limitation of today's work to minimum effort solutions. Interest in avoidance of environmental loads triggers a lot of arguments against business activity and this may aggravate the short-term bias in business today.

BUSINESS DYNAMICS AND RESOURCES

System dynamics modelling has been used to combine technologist and environmentalist views on resource management (Saeed 1996) and by, for example, Senge to clarify the resource concept. The conceptual limitations in models where the stocks of resources only have outflows have been illustrated by Acharya and Saeed (1996). There is an apparent paradox in the common understanding of the resource concept. We tend to conceptualise a raw material as something valuable given by nature, although we know that in fact the value is only understood when the material is useful to humans. Consequently, there is a need for a change of perspective.

Resources do not pre-exist, they evolve. Raw material resource values emerge with the development of knowledge about their usefulness, for example iron ore was not a resource before humans learnt to produce and make use of iron. There are positive feedback loops from activity output to potential for future input. Traditional economics with its basis in scarcity thinking and environmental accounting of resource depletion is not sufficient to generate the required level of insight. The sustainability challenge relates to both negative and positive feedback effects on common resources, see Figure 1. The negative part of this loop is already in focus. The positive part of the external feedback tends to be neglected, both by economics and by environmental sciences.

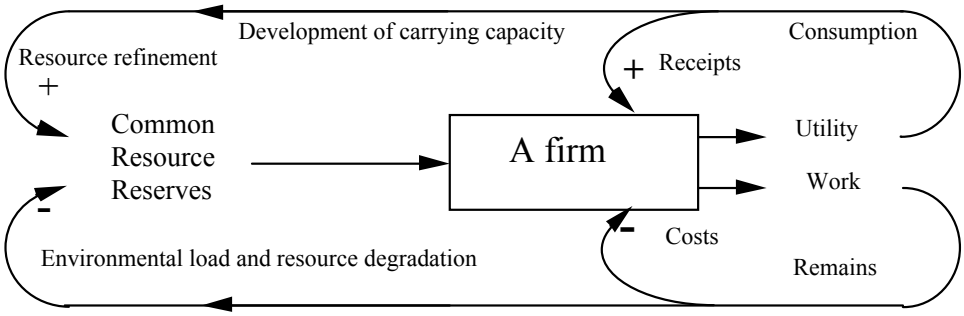

Figure 1: A sustainable business development view on a firm in a dynamic resource model (Karlsson 1998)

We want the activities that generate resource improvements to take market shares from companies that neglect sustainability issues. The environmental movement is interested in both the avoidance of negative impact and the promotion of activity with positive long-term effect. But, resource "production" is hardly included in today's environmental assessment methods. In a long-term perspective this is critical, because all activities have some negative environmental effects, and activities that contribute to system improvement for the future normally require more present activity than short-term alternatives. The environmental movement's pressure for change seems to promote eco-efficient businesses. However, heightened consumer awareness of accumulated industrial wastes has led to regulatory actions to reduce waste, and the resulting increase in costs for regulatory compliance tends to constrain profits and this may counteract investment in 'clean' technologies (Schley & Laur 1996). This indicates that promotion of eco-effectiveness may be preferable to regulations such as waste taxes.

The processes that can connect activity to improvements are experience, learning and creation of knowledge. Learning should give priority to environmental considerations. However, the environmental interest should not be conceptualised as a counterforce to other human interests. Karlsson et al. (2000) suggest that the environmental concern should be used in combination with business goals. This model indicates how the sustainable part of business can grow through reinforcing learning and business development. One way to organise such learning, through appropriate feed-back, is to use standardised environmental management systems.

ENVIRONMENTAL MANAGEMENT

The direct goal for Environmental Management Systems (EMS) is to protect human health and the environment. EMS has its conceptual starting point in the traditional environmental interest to reduce environmental load. The environmental management ISO 14000 standards also mention positive environmental impacts, and it is a main priority to relate the environmental work to other business priorities. EMS is a tool to establish and maintain communication with interested parties, and to establish a process for achieving targeted performance levels. An effectively implemented EMS system provides a framework to make use of environmental information and motivation in combination with traditional business priorities.

Environmental management is intended to be an integrated part of the organization's overall management system. "An EMS is best viewed as an organizing framework that should be continually monitored and periodically reviewed to provide effective direction for an organization's environmental activities in response to changing internal and external factors" (ISO 1996). A key principle is to accomplish continual improvement of both environmental impacts and the performance of the EMS itself. The standard states that the environmental management is among the highest corporate priorities.

LEARNING THROUGH MODELLING

Effective decision making and learning in a world of growing dynamic complexity requires us to become systems thinkers – to expand the boundaries of our mental models and develop tools to understand how the structure of complex systems creates their behaviour (Sterman 2000). Today's business and industrial problems are complex and often require holistic, inter and multi-disciplinary systems perspectives for sustainable solutions. Traditional engineering education deals with specific problems in isolated and limited contexts, and this has been criticized, for example by industrial firms. Consequently, Chalmers University of Technology has a number of activities aiming at making use of life cycle views, systems thinking and problem oriented education.

The School of Technology Management and Economics curriculum has a modelling and simulation course with Powersim exercises, on models of corporate systems and business processes. Furthermore, the faculty's research education includes systems thinking seminars with guest lecturers, such as Pål Davidsen, David Ford (both from Bergen, Norway), Van Akre (London Business School) and Cristian Kampmann (Denmark). One goal is to enable use of systems thinking and system dynamics methodology in research work.

The modelling is conceptualised as a way of learning to work with thoughts about changes of reality, by means of experiments in a virtual reality. The problem perception and conceptualisation, system models, simulation data and comprehension of the governing structures are iterative processes as shown in Figure 2.

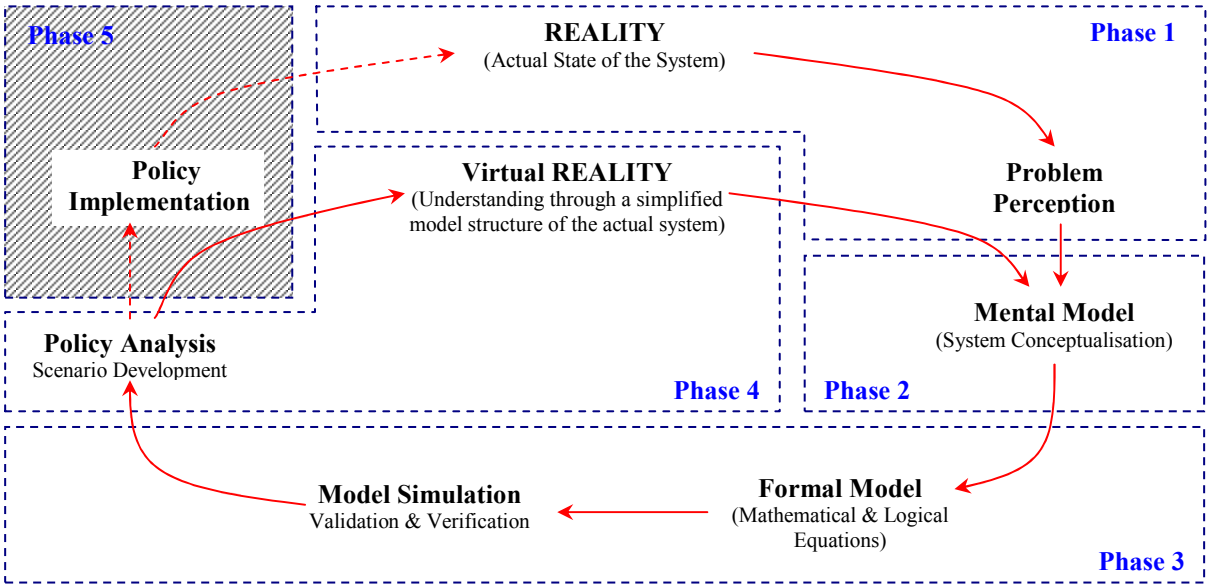

Figure 2: Phases in a Modeling and Simulation Study (Nasir 1999)

In 1998, the School of Civil Engineering introduced a compulsory *systems thinking and modelling* course for the second year civil engineering master's students. The intention is to develop skills to analyse and understand problems in an integrative framing, i.e. to enhance the students abilities to perceive reality, identify and analyse problems, design appropriate suggestions for improvement and solution, and analyse the dynamic consequences of their suggestions. The students work with Powersim modelling in projects of their own choice. One of their areas of interest is the environmental aspect of business activities. Some of the student projects are listed below:

1. Water Quality in the Gothenburg Region: Capacity Requirements for a Water Treatment Plant
2. Effects by Road Maintenance on Accidents, Traffic and Environment.
3. AIDS and HIV in Sweden: Analysis and Policy Design
4. Drugs, Unemployment and Intensity of Criminal Activities
5. Forest and Timber Market: Effects of Economic Cycles
6. Optimising Recycling of Construction Materials: A Company Perspective
7. Öresund Bridge: Effects of Tolls on Traffic

The project work has four phases - Abstraction from reality, perception or conceptualisation, formalization, and verification & validation of simulation models. Simulation models are successively developed from verbal model to conceptual model and from conceptual to formal stock-and-flow model. While submitting their project proposals, the students get training in abstracting the problem and describing it verbally. From this verbal model, causal loop diagrams are developed and finally simulation models in Powersim.

The course is quite popular and appreciated. Most students like the structured approach of assessing a problem from a long-term perspective, before starting to solve it. They believe that the systems thinking approach gives a new problem perspective that enables them to search for sustainable solutions.

LEARNING TO MAKE USE OF ENVIRONMENTAL KNOWLEDGE

The university in Dalarna has a high priority goal to develop interdisciplinary courses that enable the students to understand the sustainability challenge. The Bachelor of Science programmes on Environmental Engineering and Industrial Economics have a main ambition of learning to make use of environmental information and motivation in development of business opportunities.

The last year of the programme contains ten weeks of half time studies on *Sustainable Product Development* and twenty weeks half time on *Environmental management*. This series of courses can be interpreted an agent for cultural transmission and cultural change. In a similar way to that suggested by Kennedy (1997) we try to achieve a "thoughtful, participatory transfer of knowledge from one generation to the next". One principle to be conveyed is that: "you must assume that you can be wrong" (Bowden,1998). When working with environmental management it is important to listen, and to try to understand various counter-arguments. There is no clear answer book, and that is a frustrating experience for many students. However, the educational aim is to transfer this knowledge, and to do so with a feeling of how uncertainty is something that one has to learn to live with. In the work with industrial development processes it is important take the visions seriously, and to be able to use the arguments for change in a forceful way. One way to convey this is by having a number of guest lecturers from industry. Most of the curriculum is based on problem based learning in industrial projects.

Our view on the possibilities of environmental work is inspired by evolutionary naturalism as described by Hutcheon (1996). We aim for a form of work that makes use of the "after-the-fact causality", i.e. to be able to learn from the consequences of what one does, or does not do. On one level the project goals are to analyse and make reports, e.g. on Life Cycle Assessments (LCA) and Environmental Aspect Inventories. The pedagogical goal is also that the students should learn through their own experiences of how people react to new methods and new perspectives. For example, the students get the task of finding their own project tasks where they are to use the methods that they are about to learn. This means that they have to involve in "marketing" of something which they do not really know about. And later on they meet some reactions to the expectations that they themselves have created. This setting is intended to provide possibilities of learning from real life use of new ideas and new methods. One aim is to clarify interrelations between environmental priorities and other development goals. The courses discuss how sustainable development is dependent not only on avoidance of negative impacts, but also on promotion of activities with positive long-term effect. From the engineering point of view, it is important to make environmentally sound products. However, such products will be of no consequence, in the market evolution, if they do not sell. It is equally important to communicate the advantages of the environmentally preferable products. From this point of view, the product performance is essential. To achieve a high eco-efficiency, for the total system of products, we want to make good products with high market potential.

Sustainable Product Development

This course has a basis in environmental Life Cycle Assessment (LCA) and also process oriented methods, such as Quality Function Deployment (QFD) and Failure Mode and Effect Analysis (FMEA). A main goal is to understand the importance of life cycle considerations and to design sustainable product life-cycles (Karlsson 1999). The students have a basis in earlier courses about waste management and recycling and in this course we also deal with the environmental relevance of appropriate initial selection of materials and product design.

In the integration of environmental priorities and other development goals we use a systems view that includes added resource value, see Figure 1. To facilitate explicit dialogue about relations between different parts of the product life cycle and different forms of environmental loads we use the LCA tool EPS (Environmental Priorities Strategies) (Ryding et al 1993). The textbook is based on a similar form of interdisciplinary work, in the Swedish Product Ecology project, where the aim was to make LCA readily useful for industrial application.

Environmental management courses

The curriculum contains two EMS courses, with a start in the standards ISO 14001 and 14004, and dealing with their application in business development. The basic aim for the first part is that the students should develop skills to work with EMS. The students have been working with initial environmental reviews, identification of environmental aspects and evaluation of associated environmental impacts, in industrial projects. Some of the projects, e.g. for paper management at the university, have suggested new environmental objectives and targets.

The second part has seminars on development oriented literature, in relation to the EMS standards. The aim is to develop understanding of how the goal of continual improvement can be achieved. The seminars deal with both environmental literature, such as *Factor four* (Weizsäcker 1997) and *Beyond the limits* (Meadows et al 1992), and business oriented literature, e g *The Innovators Dilemma* (Christensen 1996) and *Managing Business Relations* (Ford et al 1998). The resulting insight is used for refinements of the projects from the first part, as a clearer guidance for implementation of environmental management programmes.

STUDENT REACTIONS AND LEARNING IN DALARNA

This section summarises a student report by Bergeå and Jonsson (2000), on reactions during a 30 week period when the above courses by Karlsson were studied half time. The courses are part of the last year of the *Environmental Engineering* programme, at the university in Dalarna. Bergeå has educational experience as a teacher for younger children and Jonsson has acted as a student representative for the class.

The report was made as a concluding part of the *Environmental Management* course. The aim was to show the students' expectations before the start of Karlsson's courses, and how the students' interest has changed during the courses. The study has a foundation in Bergeå and Jonsson's own experiences as students, and interviews with class-mates. The starting point for the project view was as seminar work on *The fifth discipline* (Senge 1990) that triggered many thoughts on environmental management systems as a tool for learning organizations.

Bergeå and Jonsson: At the beginning of the last year of the programme we students had a great urge to get all the skills that we thought we would need in our future positions. We were looking for explicit engineering skills, to be able to get out and solve the environmental problems. Our ideas of what *Environmental Engineering* actually is about were somehow ambiguous. Our ideas about *Environmental Management* were quite vague.

The initial student reaction in august 1999 was that the courses by Karlsson did not meet our expectations. Instead, Karlsson dealt with how the environmental issues are parts of greater and more complex systems in companies, organizations and society, systems that also have many sociological and process oriented aspects. This meant that many traditional, and sometimes intuitive, views were challenged.

Gradually we understood that the environmental problem is not just to be solved. We realised that life cycle considerations are not only about conflicts between environmental priorities and business profit. A solution to one environmental problem may create other kinds of environmental problems in other systems, and in the long run. We noted that there are many forms of balance between long-term and short-term interests, furthermore, that the business development on the market is important, and that the business success is dependent on many forms of interrelations to other systems. For example, the lectures on system dynamics and exercises with Powersim have shown us a new way to find the real problem, in a similar way to that described by Senge (1990).

The industrial projects with resource oriented life cycle assessments, with explicit environmental values from EPS, environmental aspect inventories and numerous discussions lead to a new way of thinking. This process can be described as a development of new mental models. The change in our perception of what an EMS is, and should be, is one aspect of this. At the start of the course, one student described EMS as yet one more tool for the managers to have it their way, a way to control the decision-making and technical process. In the progress of our schooling this view has changed. Many students now think of the leader as a person who is to develop shared visions of environmentally sustainable development, and help his co-workers to make their own decisions, not make the decisions himself. This mental model seems to help the students to understand leadership as a social system. In this way we have come to perceive the EMS as a form of being that lives organically, together with all the parts of the organization, irrespective of the fact that it consists of individuals or social groups. The development in the students' perception resembles Senges "working with mind models".

In the first contact with Karlsson's way of working, our mind models got disturbed in a fundamental way. His way of attacking problems and discussing the concept of environmental management was, for most students, a new way of creating pictures of reality. Most students wanted ready-made methods and clear answers, but many times we just got new questions. The class did not have any experience of this way of discussing things, and very soon friction became evident. This friction was sometimes so strong that a number of irritated words were said. The question now is: was this friction caused by "faults" in Karlsson's lecturing, or is the problem deeper, or of a different character? According to Senge, the concept personal mastery includes the skills of widening and in depth seeking ones own visions, collecting energy, developing ones patience and seeing things as they are without prejudice. The ability to see beyond personal disagreements and in a dedicated way learn truly new things is a very important quality. This was weak in our class. The first weeks, the sometimes personal antagonism towards Karlsson's teaching was a strong feeling at the lectures, and many hard words were said during the short breaks, words that are an expression for the frustration felt when you "don't get it". During the courses, this type of words got more and more rare. The interaction developed into a dialogue between a number of learning individuals. This is interpreted as a positive development of personal mastery.

A unified formation of a vision is a potent way to enhance the motivation to learn. With a shared vision, people will learn because they want to, not only because someone is telling them to. One characteristic for good visions is that they are felt to be relevant both for the individuals themself and to their common objective. When a vision is formulated, consciously or unconsciously, the value of the organization increases.

It is difficult to specify a vision for sustainable development, and also for *Environmental engineering*. At a basic level, the class has a shared vision to "save the world". This is, in itself, a very strong vision, but also the only one that we have been able to find. We still want more specific goals, so that we can feel and communicate a shared vision. But at least, we now understand a bit more about how the ability to learn and relearn has high relevance for human sustainability objectives.

RESULTS AND CONCLUSION

The above experiences indicate a deep change in students' conception of EMS, during the use of development oriented systems thinking in industrial projects. Bergeå and Jonsson's report also suggests that there is a need for social or sociological studies on the learning needed to enable use of EMS for a sustainable development.

One hurdle for environmental work is that interdisciplinary translation causes deformation of information. To handle this it is essential to establish a familiarity with the systems view that generate and use the information. To be able to make use of environmental information there is a need to understand business practices. "The only way the students will learn to approach their learning differently is by experiencing a different kind of learning environment"(Bowden 1998). Both the modelling at Chalmers and the EMS studies in Dalarna show the most effective learning when the students participate actively in the development of the mental models they study.

The environmental class in Dalarna wants to "save the world". This ambition contained enough energy to learn a new perspective for environmental work. It takes more than lecturing on environmental facts to build such energy. The sustainability challenge contains a need to rethink, at a level that may be quite frustrating. To support the needed learning, it is necessary to be prepared to deal with such feelings and to engage in activities that generate a relevant form of experience. The question is not only what to teach, but also how to learn.

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