Journal of Sustainability Education
Vol. 6, May 2014
ISSN: 2151-7452

Essential Elements of Sustainability Education Template

Brigitte Bollmann-Zuberbühler
Patrick Kunz
Ursula Frischknecht-Tobler
Pädagogische Hochschule St.Gallen

Key words: Sustainable Development, Systems Thinking, SYSDENE, multi-dimensional

Name:	Brigitte Bollmann-Zuberbühler, Patrick Kunz, Ursula Frischknecht-Tobler
Email:	Ursula.frischknecht@phsg.ch

Learning Outcomes

Enduring Understandings/Big Ideas:

Before you even start with Sustainability *Education*, it is necessary to work on the attribution of significance of Sustainable Development (SD). Pupils, students, teachers or lecturers alike: they all need to recognize sustainability as something important and significant and then they will be perceptible to the concepts of SD.

Furthermore, it is important for teachers to keep the cost in time and effort low for incorporating elements of Education for Sustainable Development (ESD) in their courses. This can be achieved by by showing teachers how to integrate ESD into various subject matters. This concomitantly also deals the third challenge: The integration of ESD into mandated curriculum content.

ESD topics are multidimensional (economical, ecological and social dimension). *Systems Thinking* gives an answer how to deal with that inherent complexity. Nowadays, Systems Thinking is used in science, technology, economics as well as in psychology or sociology. General principles of Systems Thinking help to find a shared language to discuss interdisciplinary problems typical for ESD.

However, research in science education has shown that students from primary to higher education as well as teachers themselves have a poor understanding of basic systems concepts (e.g. Booth Sweeney & Sterman, 2007; Skaza et al., 2013). Thus, the need to learn about systems as an important element of ESD is evident.

Content Knowledge:

In Europe, *Systems Thinking* is considered one of the main pedagogical principles of ESD (Kyburz-Graber, Nagel, & Odermatt, 2010, Rieckmann, 2011), because it helps to address the multidimensional aspects
of sustainability and tries to understand and manage complexity.

In addition to analytical thinking, Systems Thinking aims at a deeper understanding of interdependencies, circular causality and dynamic complexity such as delay and non-linear changes. Teaching Systems Thinking in school intends to qualify pupils for dealing with complex ESD topics.

Encouraged by intervention studies revealing that Systems Thinking can successfully be taught in schools (e.g. Ossimitz, 2000; Plate, 2006; Sommer, 2005) teaching materials have been developed based on the following definition: *Systems Thinking comprises the ability to describe reconstruct and model complex sectors of reality as systems. The model building process serves to give explanations and forecasts and judge them while allowing for the chance of happening and considering the limits of the model (Frischknecht et al., 2008).*

Skill Sets:

The definition lead to a model of competences of Systems Thinking (Figure 1) we used to visualize the process of understanding complexity. The model includes four areas of competences.

1. The first area of competence (model description) includes defining the boundaries of a system, identifying its elements (knots) and the cause-effect-relationships between these elements, in particular causal loops. Model description usually leads to a causal loop diagram.
2. The second area of competence implies the identification of changes such as nonlinearity, time delays, limits of growth. Changes are normally visualized by time graphs. The red double ended arrow indicates that these competences develop simultaneously.
3. Reconstructed system models can be used to make predictions on future developments (third area). Working in this area of competence including circles and archetypes important for ESD such as the tragedy of commons or limits to growth (Senge, 1996).
4. The fourth area comes as a consequence of the other three areas of competence and includes the conceptualization and the assessment of action plans, leading eventually to taking actions within systems.

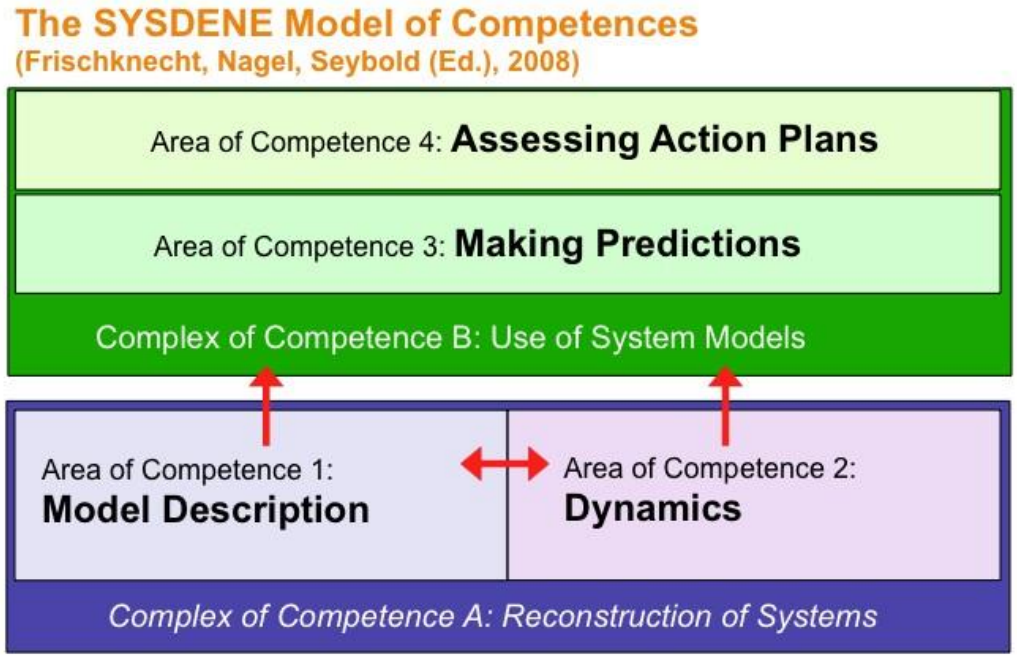

Figure 1: competence model of the Swiss-German Research group

Attitudes:

Working in the field of ESD as well as Systems thinking, it turned out that the habits of a Systems Thinker provided by the Waters Foundation (http://watersfoundation.org/systems-thinking/habits-of-a-systems-thinker) are an excellent set of important attitudes that need to be addressed when teaching ESD. We highly recommend to pursue the following eight core habits in the context of ESD:

1. Seeing the big picture: I keep my focus on the whole system rather than just on its parts.
2. Changing perspective: I look at the things from different angles.
3. Considering interdependencies: I see what fits together and belongs together.

4. Tracking changes: I discover how things and relations change over time.
5. Considering durations: I think about short and long term effects.
6. Recognizing effects: I find out what consequences actions can have.
7. Optimizing actions: I review the system's structure and its outcomes and change my actions if necessary.
8. Developing the system: I look out for ways to improve the functioning of the system.

Behaviors and Actions:
Systems Thinking helps to understand complexity and to evaluate behavior and plans of action. Specific actions taken depend on topics, teachers choose to introduce Systems Thinking in their class.

The Classroom or Educational Setting

Curriculum, Instruction and Assessment Practices Aligned With Learning Outcomes:

Based on our competence model we developed the following sequence of introducing systems thinking into the classroom:

Step 1: Identify boundaries and elements of the system in question
Step 2: Describe causal connectedness
Step 3: Draw causal loop diagrams and identify feedback
Step 4: Describe changes with behavior over time graphs
Step 5: Differentiate between linear and non-linear growth / decline
Step 6: Identify delay
Step 7: Deduce forecasts
Step 8: Evaluate plans of action

All steps include a bunch of activities to use and reflect in class in order to learn about concepts and to apply diagrams, attitudes and habits of Systems Thinking.

Characteristics of Authentic Engagement:

Systems Thinking can be taught in all grades and classes (see also Fisher 2011). The following examples show three different approaches to Systems Thinking with an ESD-topic. In all projects pupils learned important systems concepts, used the tools and discussed habits and attitudes.

(1) 1st/2nd grade: A story about a colony of mice living on an island had been used by a teacher to introduce basic concepts of Systems Thinking. Since the story has a sad and a happy ending according to how the mice population reacts on the fact that one of the mice finds a unique glittering stone everyone wants to possess. In this story it is possible to identify the system and its elements and pose the crucial question that leads to identifying connections and first interdependencies: What if…. And then….

(2) Fourth/Fifth grade: A project in classes combining language, design, natural and social sciences: Students developed a map of their ideal village. A public presentation led to discussions about childrens' needs. During the project, students learned to express their desires about such as play grounds and green areas but also to think about others needs such as public transportation, public buildings, shops or home for elderly. They learned about traffic-problems and the values of ecological compensation areas using Systems Thinking.

(3) Eighth grade: project in geography: Students learn about the effects of the introduction of the Nile perch to Lake Victoria, how it has affected the ecosystem and economy of the region. In addition, the film "Darwins nightmare" illustrates drug and prostitution problems triggered by appalling living and working conditions. Systems Thinking is needed to visualize and to understand interdependencies of local peoples needs and the consequences of Fish industry to their living. Students learn about long term consequences their consumers' behaviour.

Schools/Institutions

Favorable Conditions—Organizational Policies and Practices:
The introduction of ESD into an educational institution can be fostered by the following points of action:

- Before starting to dwell on ESD-teaching material, teaching staff has to recognize ESD as important. This sounds trivial, however many well intended initiatives omit to work on the attitudes of teachers and go straight to how to teach ESD.
- The relation of ESD to the mandated curriculum has to be shown with practical examples.
- Costs in terms of time and the preparation or adaptation of teaching material have to be kept low or the necessary resources need to be provided.

Communities

Characteristics of Institution-Community Partnerships:
-

Narrative Explanation of Essential Elements

Sustainable development is multidimensional. It encompasses social, cultural, economic and environmental aspects in their interdependencies with regard to space and time. Education for Sustainable Development (ESD) meanwhile is finding its way to school. K-12 curricula contain topics such as climate change, energy supply and consumer education which can be taught as ESD units. Their complexity is challenging teachers and students alike.

In Europe, Systems Thinking is considered one of the main pedagogical principles of ESD (Kyburz-Graber, Nagel, & Odermatt, 2010, Rickmann, 2011), because it helps to address the multidimensional aspects of sustainability and tries to understand and manage complexity. Systems Thinking complements analytical thinking in different ways:
In contrast to linear analytical thinking, it aims at a deeper understanding of the whole, the interdependencies, circular causality and dynamic complexity such as delay and non-linear changes. In addition, a systemic view helps us to recognize how our subjective self is involved in perception and interpretation of events and fosters remaining flexible and adaptive.

Nowadays, Systems Thinking is used in science, technology, economics as well as in psychology or sociology. General principles of Systems Thinking help to find a shared language to discuss interdisciplinary problems typical for ESD. However, research in science education has shown that students from primary to higher education as well as teachers themselves have a poor understanding of basic systems concepts (e.g. Booth Sweeney & Sterman, 2007; Skaza et al., 2013). Students' reasoning in complex situations is often restricted to linear arguments and to applying linear models to predict changes of a parameter. Thus, the need to learn about systems as an important element of ESD is evident.

On the other hand, intervention studies revealed that Systems Thinking can successfully be taught in schools (e.g. Ossimitz, 2000, Plate 2006, Frischknecht-Tobler et al., 2008). As a consequence of a cross-curricular training, students were able to use more structurally complex relationships and draw causal chains as well as feedback loops to outline a complex situation. Additionally, they recognised more non-linear changes and formulated more sophisticated predictions, including alternative reasoning, delays and limits of growth (Bollmann-Zuberbühler, 2010). However, until now systems oriented education did not spread broadly although great materials from K-12 exist and Systems Thinking is seen as a unifying cognitive means in science curricula, such as the one in Washington State (Dorn, 2009). Systems Thinking can be fostered by showing teachers how to integrate it into various subject matters, thus helping them to keep the cost in time and effort low. A recent study (Frischknecht-Tobler et al. 2013) showed that besides the attribution of significance this proved to be a crucial factor for the introduction of Systems Thinking into the classroom.

Due to the existence of different definitions of Systems Thinking (e.g. Forrester, 1994; Richmond, 1994; Ossimitz, 2000, Waters foundation (without year)), the adoption of a coherent framework was needed to conduct the study. A definition and a competence model was developed in a joint Swiss-German research-group Systems Thinking

The following definition laid the foundation for the development of teaching materials and for further studies: *Systems Thinking comprises the ability to describe reconstruct and model complex sectors of reality as systems. The model building process serves to give explanations and forecasts and judge them while allowing for the chance of happening and considering the limits of the model.*

The competence model (Figure 1) includes four areas of competences.

The first area of competence (model description) includes defining the boundaries of a system, identifying its elements (knots) and the cause-effect-relationships between these elements, in particular causal loops. Model description usually leads to a causal loop diagram.

The second area of competence implies the identification of changes such as nonlinearity, time delays, limits of growth. Changes are normally visualized by time graphs. The red double ended arrow indicates that these competences develop simultaneously.

Reconstructed system models can be used to make predictions on future developments (third area). Working in this area of competence including circles and archetypes important for ESD such as the tragedy of commons or limits to growth (Senge, 1996).

The fourth area comes as a consequence of the other three areas of competence and includes the conceptualization and the assessment of action plans, leading eventually to taking actions within systems.

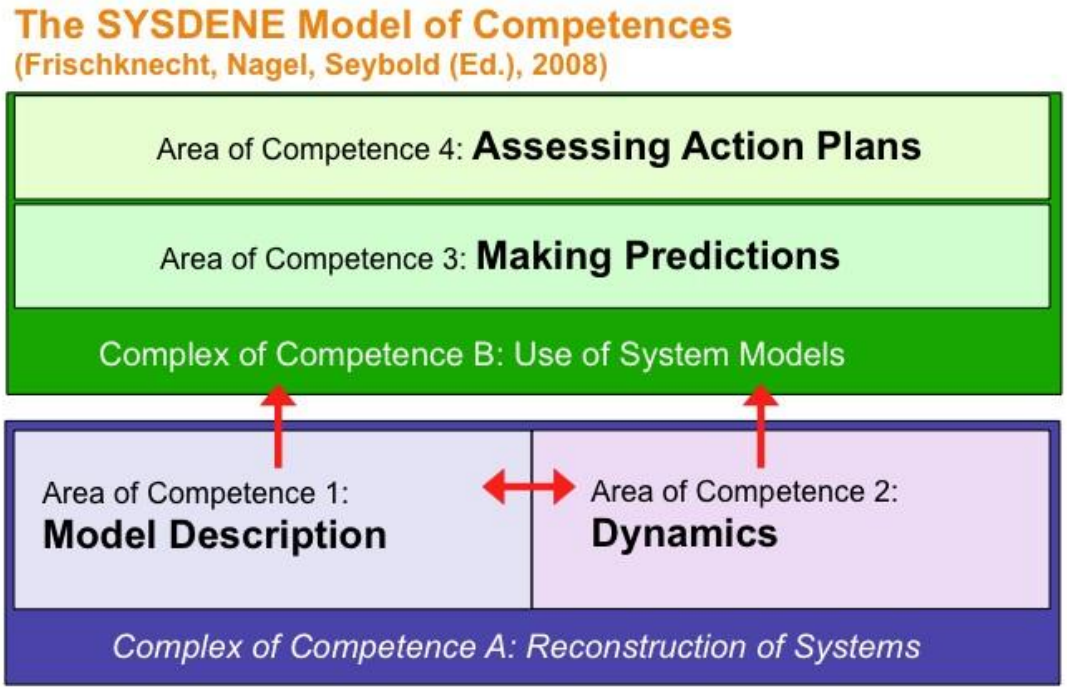

Figure 1: competence model of the Swiss-German Research group

Working in the field of ESD as well as Systems thinking, it turned out that the habits of a Systems Thinker provided by the Waters Foundation (http://watersfoundation.org/systems-thinking/habits- of-a-systems-thinker) are an excellent set of important attitudes that need to be addressed when teaching ESD.

Based on our competence model we developed the following sequence of introducing systems thinking into the classroom (Bollmann-Zuberbühler, et.al, 2010):

Step 1: Identify boundaries and elements of the system in question
Step 2: Describe causal connectedness
Step 3: Draw causal loop diagrams and identify feedback
Step 4: Describe changes with behavior over time graphs
Step 5: Differentiate between linear and non-linear growth / decline
Step 6: Identify delay
Step 7: Deduce forecasts
Step 8: Evaluate plans of action

Literature

- Bollmann-Zuberbühler, B., Frischknecht-Tobler, U., Kunz, P., Nagel U. & Wilhelm Hamiti, S. (2010). *Systemdenken fördern. Systemtraining und Unterrichtsreihen zum vernetzten Denken.* Bern: Schulverlag.
- Bollmann-Zuberbühler, B. (2010). *Systemisches Denken an der Sekundarstufe I. Eine Interventionsstudie.* PhD-thesis. Zürich: Zentralstelle der Studentenschaft der Universität Zürich.
- Booth Sweeney, L. & Sternman, J. (2007). *Thinking about systems: student and teacher conceptions of natural and social systems.* System Dynamics Review 23, 285-312.
- Dorn, R.I. (2009). *Revised Washington State K-12 Science Standards.* Online unter: www.sbe.wa.gov/documents/WAScienceStandardsDec4.pdf (5. Jan. 2010).
- Frischknecht-Tobler, U., Nagel, U. & Seybold, H.J. (Hrsg.). (2008). *Systemdenken. Wie Kinder und Jugendliche komplexe Systeme verstehen lernen.* Zürich: Verlag Pestalozzianum.
- Fisher, D. M. 2011. "Everybody thinking differently": K-12 is a leverage point. *System Dynamics Review*, 27(4): 394-411.
- Frischknecht-Tobler, U., Bollmann-Zuberbühler, B., Kunz, P., Strauss, N-C. (2013): *Förderung von Systemdenken in der Volksschule.* Schlussbericht. PHSG und PHZH.
- Kyburz-Graber, R., Nagel, U & Odermatt, F. (Ed.) (2010). *Handeln statt hoffen. Materialien zur Bildung für Nachhaltige Entwicklung für die Sekundarstufe I.* Zug: Klett und Balmer Verlag.
- Plate, R.R. (2006). *Assessing the Effectiveness of System-Oriented Instruction for Preparing Students to Understand Complexity*. Gainesville, FL: University of Florida.
- Ossimitz, G. (2000). *Entwicklung systemischen Denkens. Theoretische Konzepte und empirische Untersuchungen.* München: Profil-Verlag.
- Rieckmann, M. (2010.): *Die globale Perspektive der Bildung für eine nachhaltige Entwicklung – Eine europäisch-lateinamerikanische Studie zu Schlüsselkompetenzen für Denken und Handeln in der Weltgesellschaft.* Phd-Theses (Bd. 7). Berlin: Berliner Wissenschaftsverlag.
- Skaza, H., Crippen, K. J., Carroll, K. R. 2013. Teachers' barriers to introducing system dynamics in K-12 STEM curriculum. *System Dynamics Review*, 29(3): 157-169.