HOW CAN THE EDUCATIONAL SYSTEM ENHANCE THE CAPABILITY OF SYSTEM THINKING?

Barbara Brock, Anja Janischewski

Karl-Franzens University, Graz, Austria

e-mail: Barbara.brock@hotmail.com or anja.janischewski@edu.uni-graz.at

ABSTRACT

Climate change requires a reduction of the use of fossil resources – on the same time we still use more and more of them. – On one hand everyone wants to earn as much money as possible and on the other hand we want the government to pay for social security, education and other common needs. – Husband and wife are annoying each other and everyone blames the other one for being guilty.

These are just a few examples to demonstrate, how helpful system sciences could be in solving such problems. Looking back at our own school time we recognised, that in fact already children are able to think in systems in a certain way. Always when children or people in general learn anything new, they connect it to something they already know. Before we enter school, we are used to interdisciplinary learning, in school we start to section our knowledge into subjects.

The main flaw is represented by the fact that most of the exercises are set up in a manner that children are trained to unlearn system thinking. When we are adults, it is quite hard to change our thinking pattern. It is paradox that we try to learn something being an adult that we already knew as a child. Therefore we want to search for methods how to enhance the capability of system thinking during education in general.

Another reason why we chose this topic is that we are kind of specialists on it, because we just came from school and are attending the university. During our education we got to know methods to include system thinking and we want to share our experiences with you. Further more we looked for projects or methods, which already exist. For example:

1. "Netzwerk" – network, a project of interdisciplinary learning at a school in Austria
2. "Umweltsystemwissenschaften" – environmental-system sciences – a study course at the University of Graz, Austria
3. The experimental game "Schule als Staat", in English: "a school transformed into a state" which took place at a school in Germany
4. Ecopolicy® - the cybernetic strategy game by Frederic Vester

How can the educational system enhance the capability of system thinking?

To evaluate these methods we asked users about their experience with them. In general we dealt with the following questions: How does the method work in general? What are the important points you should remember while introducing system thinking into educational systems? What are frequent problems that occur and which solutions can be found? Using this knowledge, we thought about ideas how to include system thinking in our education in a better way and wrote them down. Further more we made an analysis how system thinking in schools would affect our education and in the end the whole society.

Keywords: educational system – system thinking4

1) THE IMPACT OF SYSTEM THINKING IN OUR EDUCATION

The first and one of the most important points is that the earlier we start to include system thinking in our every day life and in our education, the better it will work. We start thinking and thus understanding with our first heartbeat and this is why we should start thinking in systems as early as possible, because the best imaginable result would be that we would be able to avoid further ecological, economical or social problems.

In our childhood and our youth we learn how to think. Therefore everything in our childhood is influencing our way of thinking as adults. That are thoughts that apparently everyone knows nowadays, but are not paid regard enough. Most people can tell an example like this: “Oh, I'm so bad at French, my French teacher was so horrible, that I didn't want to learn and always had bad marks.”

So if system thinking seems so important in our days, how should education look like, to enhance this capability?

Moreover: Our mind is connecting new information to older ones, creating new connections, associating all the time. That is also the way, we remember facts: we connect them to knowledge we already have. How could school look like, to enhance this way of thinking? How should education be to avoid unlearning our way of network thinking?

For these questions we tried to get answers while looking at the following points:

1) Are the students able to understand a complex exercise or are they rather afraid of it?

2) Do students often have light bulb moment as a result of an exercise, which should teach them how important the linking of different subjects is?

3) Are different teaching methods (visual, auditive, motoric etc.) used

4) Does this project rather teach the background philosophy of system thinking or does it rather teach this way of thinking itself?

5) Which aspects of the following are furthered:

    1. Autonomous linking of different subjects

    2. Autonomous linking of new knowledge to old knowledge.

    3. The ability of holistic recognition

    4. The awareness of feedbacks and temporal delays

5. The skill to differentiate between more or less important information
6. The competence to use the knowledge about feedbacks, temporal delays, interactions and the system structure in general for improvements
7. Reducing the fear of complexity

1.01) "Netzwerk"-network

1.01) a) Outline data

This project was invented in my (Barbara Brock) school "Akademisches Gymnasium Innsbruck" in the school year of 1999/2000.

1.01) b) Basic concept

The main principles of network are:

1. Working interdisciplinary
2. Developing autonomy and personal responsibility and an autonomous way of thinking
3. Furthering social competences

Of course the first point is the most important regarding our topic: Working interdisciplinary means that one topic is seen from different specialities and that each of them deals with it form its point of view. This way of learning leads the students to thinking in different subjects and they register that one topic can never be allocated with only one field. Further on one could say that autonomous thinking and taking responsibility for oneself is the basis for system thinking. The third point plays a very important role too, because the students have a special subject, with the aim of teaching them soft skills, which are needed to make good presentations and to work together in groups.

1.01) c) Why did we select "Netzwerk"?

This concept as a special way of education for girls and boys at the age of 10 to 18 is an example for including system thinking into schools.

1.01) d) How does "Netzwerk" work in practice?

Of course many teachers say that they do not want their students to think in one way only, but often it is just like that in school and in this system everything is done to avoid this: In the first four years of school the students get a timetable which is concentrated on one topic looked at from different points of view. Then they see what their tasks are, in which subject and they also have to manage their time by themselves. Later on the rules are not that strict anymore and they just get one topic and then it is their work to deal with it.

1.01) e) Evaluation of concerning the five "system-thinking-questions"

1. The longer students learn in this way the better they get used to complex questions. But of course it depends on the student how many years this takes.
2. The frequency of light bulb moments is also depending on the student, but I think that they happen very often at the age of 15.

3. The variety of teaching methods is really big.
4. This project does not teach the theory of system sciences, only the realization of system thinking. The focus is based on linking abilities between different subjects.
5. Which aspects are furthered?

    - Autonomous linking of different subjects
    - Autonomous linking of new knowledge to old knowledge.
    - The ability of holistic recognition
    - The skill to differentiate between more or less important information
    - The competence to use feedbacks for improvements
    - Reducing the fear of complexity

1.01) f) A field report about "Netzwerk" by Barbara Brock

I asked my class teacher about her experience with Network, because she is really into it and I would like to sum up what she wrote to me:

She agreed with me that one of the most important points is the system thinking, which should be learned by looking at a theme from different subjects. One of her fears is that the students are possibly over challenged with their tasks concerning different disciplines. But I think that is what happens in real life all the time and if we get used to think in different ways in school maybe we will be able to solve our problems later on in a better way. Now I would like to list the advantages, my teacher thought of:

- Teamwork between the teacher themselves
- Many different ways of working and learning are provided for the students and this makes it possible for students to learn in their own, personal way.
- Adopting special skills such as teamwork, independent working, research techniques, presentations etc.
- A focus on social and soft skills.
- Battening onto metacognitive skills through reflections etc.
- Students often plan whole trips by themselves.

Now I would like to proceed with the disadvantages mentioned by my class teacher:

- The framework conditions are sometimes bad because teachers often have to do more work for which they do not get paid.
- There should be a special education for teachers who want to work with network.

She also brought in some improvement suggestions for this project:

- More choices for students between different core themes.
- More praxis oriented learning and teaching.

Summarizing my teacher told me that there are three most important points for her concerning

network, which emerged with her long experience:

1. Teamwork
2. Students have to take responsibility for their work
3. Motivation is furthered by more options to put emphasis on further personal interests

1.02) "Umweltsystemwissenschaften"- environmental system studies

1.02) a) Outline data

Environmental system studies are a regular study since 2003 at the Karl-Franzens-University of Graz.

1.02) b) Basic concept

"The whole is more than the sum of its parts" – This would describe the field of study in one sentence, but I would like to explain it a little bit more:
This study offers many opportunities to choose between subjects and courses. At first you have to decide which point of special interest you prefer, there are five: chemistry, geography, physics, business and political economics. Further more you have a great range of free choice abilities concerning additional courses from other subjects, but they have to refer to environmental problems. This strategy helps us to develop system thinking.
Further more we all have subjects together to learn maths, ecology and system sciences. During group works it is really interesting to watch how people from different subjects look at a special problem. This teaches us to see everything from different points of view.
In our study we also have one course, which aim it is to give us an impression of other points of special interest. In addition to the above-mentioned courses, we do an interdisciplinary internship, which is organized by students. The aim is to choose a problem, preferably an environmental one or it should be dealing with system sciences directly, and to find a solution to it. The goal is to further our soft skills concerning group works and our system thinking.
Everything mentioned up to now furthers our joined-up thinking, but there are other aspects which should be mentioned too: One of the core themes is sustainability and that it does not work without interdisciplinarity and system thinking, because this is how we as humans interact with our environment.

1.02) c) Why did we select "Umweltsystemwissenschaften"?

We both decided to go for this study, because we wanted to learn more about the system thinking approach to understanding complex challenges.

1.02) d) How does "Umweltsystemwissenschafte" work in practice?

The implementation in general works well, but it is always depending on the subject you chose.

1. 02) e) Evaluation concerning the four "system-thinking-questions"

1. We have a subject called „qualitative system studies" and the aim of it is to show us how to deal with complex problems and in „quantitative system sciences" we learn how to work out mathematical methods to describe complex situations.

2. In "qualitative system sciences" we often had to read papers concerning special problems, which happened in the real world and of which we also heard before and I often had light bulb moments while reading, because I recognized what the real cause of a certain problem was or is (e.g. the financial crises).

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3. The variety of teaching methods is depending on the lecturer, but in general I would prefer to do more group works and less ex-cathedra teaching.

4. If you study "Environmental System Studies" you have three subjects in your bachelor-education, which really teach you the theory of system sciences, one qualitative and one quantitative and then you have to lay eye on one of these two.

5. Which aspects are furthered?

   - Autonomous linking of different subjects
   - The ability of holistic recognition
   - The awareness of feedbacks and temporal delays
   - The competence to use feedbacks for improvements
   - Reducing the fear of complexity

1.03) Role- playing game "A school, transformed into a state"

1.03) a) Outline data

„A school, transformed into a state" is the English translation for the role- playing game „Schule als Staat!" (German) that was carried out in lots of schools in Germany. The described example was organized in Summer 2007, from 18th to 21st July, in the secondary school called "Gymnasium Korntal-Münchingen", in the South of Germany. Around 800 pupils took part in the role- playing game.

1.03) b) Basic concept

Including all pupils and teachers, a school was transformed into a state. Several months before, the organisation team is designing all important symbols and institutions of the state, e.g. the economic sector and constitution. Everyone, pupils and teachers play their role in the game, either a state official, businessman/woman or worker. In general the game lasts 3-7 days, preparations last several months up to one year.

1.03) c) Why did we select "A school, transformed into a state"?

We chose it, because Anja Janischewski **3**took part in the game. It is an interdisciplinary way of learning and it deals with complexity, which pupils have to manage in some way.

How can the educational system enhance the capability of system thinking?

1.03) d) How does "A school, transformed into a state" work in practice?

What happened in Korntal, Germany, in Summer 2008 – Short revue:

For four days, the school was transformed into the "Free Democratic Republic of Fritshi-Islands", with workers, politicians, judges, police, elections, economy, press, a president (and a few scandals about him), demonstrations, compromises, own designed money, an own flag and an own anthem. All the participants of the school, pupils and teachers were involved in the state-life. They founded small enterprises like a cinema or a barbecue or had other more or less creative ideas. In the beginning, the constitution was defined, money printed, and the first laws settled. After a very creative election campaign, the real life started. Thanks to many guests who had to pay customs duty to enter our territory, the economy was growing and growing. On the third day, the protests of the lower functionaries and cleaners became quite big, the consequence was that, our government agreed finally to some compromises. Luckily, the project ended without any big catastrophes and after four days, the Fritshi-Islands became our school again.

It did not matter if you were in 5th or 13th grade, everyone could experience, how mechanisms in our model-state worked. This was one aim of the project: To learn interactively about the structures and mechanisms in a state. The organisation team tried to make their model quite similar to a real democratic republic. But soon, it was clear, that there are some big differences to real polictics: Have you ever seen a "party of hedonists" winning serious elections? Have you ever heard about all members of the government donating all their extra money to the state due to demonstrations? Nevertheless, there were a lot of parallels in the role- playing game to the real world: The inhabitants of the Republic of Fritshi Islands realized their own, quite complicated tax-system, had to deal with tax dodging, aspects like keeping a business running, they saw the subtle influences of journalism, ... and altogether they tried to keep the whole state running. Further more the participants experienced that, whatever they did, it influenced more or less the whole state. We also learned, that a lot of institutions and aspects are connected to each other: e.g. after the first day, economy was working well, especially thanks to the barbecue-business. there were more taxes, functionaries were earning more money, spend more money and finally this led to more economical growth again.

So even if the participants did not hear the word network thinking or system thinking during this project at all, everybody learned quite a bit about it in practice.

This project was already realized in many schools before and the most common problems were: Some pupils and teachers were not motivated to act in the game. Or the state collapses under a very fast monetary inflation. Nevertheless, most of the time it gave the pupils a better view on the subject state and economy.

Role- playing game as models for a complex system...
Comparing the "Schule als Staat"- project to a paperwork model of a complex system, following aspect hast to be remembered: There will always we, especially in a role-playing game, huge differences to the real world. Obviously, kids decide differently to experienced politicians and businessmen/women. On the same time, some characteristics of "human nature" observed in the game like the desire for justice or eagerness for power, make this kind of model more realistic again.

1.03) e) Evaluation concerning the four "system-thinking-questions"

1. After playing the game, pupils are still afraid of complex exercises in school, in the same way than before. Nevertheless, pupils understand the behaviour of dynamic systems better. Pupils who were in the organization team or were very proactive are for sure more confident

of complex exercises afterwards.

2. Concerning light bulb moments: There are no concrete exercises for linking different subjects. There can be light bulb moments concerning understanding of politics.
3. –
4. This project teaches rather the way of system thinking itself. It depends on your own role if you are just a little worker or if you are minister of finance, how much of system thinking you learn.
5. The following aspects are furthered:
   - Autonomous linking of different subjects
   - The ability of holistic recognition
   - The awareness of feedback and temporal delays
   - The competence to use the knowledge about feedbacks, temporal delays, interactions and the system structure in general

These abilities are especially taught to the pupils who have leading positions in the game or were part of the organization team.

1.04) Ecopolicy®, the cybernetic strategy game by Frederic Vester

1.04) a) Outline Data

Frederic Vester first created the game as a paper-version in 1980. Later, it was transformed into a computer game. Hans-Werner Hansen and Wilfried D. John, two teachers from Germany, transformed the game into a school-competition. Since 2005 the competition carried out in Germany every year. In the meantime it is also prepared in other countries. Currently, around 120 000 pupils take part in the competition.

1.04) b) Basic concept

In this strategic game, you are playing the role of a head of government of the country "Kybernetien". The political, social and economical situation in this country is very bad, and it is your task to solve these problems with strategic decisions and system thinking. There are to other main game versions: the emerging nation "Kybinien" and the developing country "Kyborien".

The system of Kybernetien is divided into nine subsystems: politics, restructuring, production, pollution, education, quality of life, growth rate, population and action points (which are equivalent to the national budget and other ways of influence). With the action points, you are able to improve four of them: restructuring, production, education and quality of life. After each playing round you can see, how your actions are changing the different subsystems, sometimes with surprising, unforeseen effects. The latest after twelve rounds the game is over, unless the people have not chased you out of the country before, due to your false decisions.

For advanced users, there are more setting options. The quality of the interconnections between the different parts of the system and also the starting adjustments can be changed there. In this way the user can create his own model of a country.

How can the educational system enhance the capability of system thinking?

1.04) c) Why did we select ecopolicy®?

This kind of game represents a big contrast to former teaching methods. At the same time, experience shows that it is possible to implement it into school life, as can be seen at the annual competition "ecopolicyade®" in Germany. We wanted to know, how it works in practise and how it is possible to establish it in a wider range.

1.04) d) How does ecopolicy® work in practice?

In every school, which decides to take part in the ecopolicyade®, several teams of two or three pupils at the age of 12 to 17 years are formed. All types of schools participate. The game is played in an online-version with specifically defined adjustments. After electing the winner-team of one school there are higher levels of competition: First between schools in one city ore region, then in one federal state and the final competition takes place in the whole republic. The winner-teams of the competition in a federal state and of the final competition compete against the respective politicians. Often the pupils win against politicians.

Maybe as a consequence, the competition is largely supported by politics and economy, as you can see in the list of sponsors.

After the contest, the school can continue using the Ecopolicy®-licence and is able to install the game on every school computer but also on private computers of pupils.

Great possibilities for using the game in further lessons appear:

- The ecopolicy®-game can be transformed into another situation by changing the names of the parameters and their interconnections. In this way, the subject of the game can be changed into a situation more adapted for kids, e.g. a situation at school or at home.

- In the lessons pupils can learn together how to deal with the program. Therefore exercise sheets and other material is provided, which is really motivating the kids to deal with the non linear connections and diagrams.

- After that, pupils can work and play on their own, in working-groups or at home, so the autonomous learning is enhanced. Pupils are told to document the actions during the game for further reflection. In the end teacher and pupils are looking back and evaluating the play-rounds.

1.04) e) Evaluation concerning the five "system-thinking-questions":

1) Pupils are not afraid of playing this game. The complexity of the game is seen rather as a challenge than something to be afraid of. The training with the game gives them more confidence in understanding other complex systems in a certain way, too.

2) After playing the game several times and dealing with the background of interconnections, pupils can definitely have a light bulb moment: The moment, when they succeed to bring their country into the state of paradise.

3) There are two different teaching methods: On the one hand there is the computer, on the other hand, there is the teamwork. Pupils discuss and decide together, which actions have to be done during the game.

4) Ecopolicy® is training both, the ability of system thinking itself by playing the as well as background knowledge about complex systems by dealing with the interconnections and

diagrams is communicated.

5) The following aspects are furthered:

- The ability of holistic recognition
- The awareness of feedbacks and temporal delays
- The skill to differentiate between more or less important information
- The competence to use the knowledge about feedbacks, temporal delays, interactions and the system structure in general for improvements

1.04) f) A field report about Ecopolicy®

On May 6th 2011 Anja Janischewski visited the ecopolicyade® event in Munich to ask some questions about the project. Teachers and students from the eighth, ninth and tenth grade were interviewed to find out how they experienced the "new way of learning".

Most pupils got a good impression of this innovative learning method. The fact that there are several ways of reaching the goal and the playful character of the game made it easier for them to get involved. Learning about interconnections in economy was fun and understanding the quite complicated, background diagrams never seemed to be a problem. They managed easily to dissolve problems based on the diagrams. Students liked the method; most of them would have liked to use it more often, also in other classes. "Ecopolicy® is fun, and having fun is always good for learning." summarized a ninth grade student. Comparing ecopolicy® to other computer games, some students would prefer another layout and illustrations in order to have a better in-game feeling.

Three secondary school teachers, one of them from Salzburg, the others from Munich, had been interviewed too. Just like the students, they mentioned having fun is the main advantage of the game. Nowadays it is important for the motivation of the children to see a link between, what they learn in school and their real life. The fact that ecopolicy® is a very practical game, and clearly showing the link to reality, it is quite popular. In ecopolicy®, the children are in the position of government. In contrast to the daily school, they have the power to decide what they are doing. This is also highly motivating. Direct feedback is another positive aspect of ecopolicy®. "Management games work fine in upper grades", said a teacher from Munich, "but they always require extra time, because the 50 minutes during one lesson is not enough". Another major problem is the schools infrastructure. At many schools, there are simply not enough computers for everyone and the ones provided are too slow to run the program properly. Experience shows the importance of leading the student through these learning methods. Ecopolicy® should not just be seen as a game, but rather as a tool for better learning. Letting the children play ecopolicy® just for fun does not seem to be quite demotivating. The students are used to entertainment on a much higher level nowadays. Besides pupils deal differently with the more complicated aspect of the game, for example the background diagrams. Some are very interested and some just play by trying without wanting to know the background relation. Therefore individual support is necessary.

All teachers approved the suggestion to implement this learning method in a wider field in school. The question is now to find the right key factors in this complex system to make a difference. According to the teachers asked, following strategies could be useful: Teachers themselves should think in a more cybernetic way and cooperate interdisciplinary more often.

How can the educational system enhance the capability of system thinking?

"The biggest problem though is the lack of time, teachers have. Organising a interdisciplinary project often means that other classes have to be cancelled." said a Munich teacher. This problem can be solved, for example by including more special project days in the school year. For some projects and learning methods it is better to have more than 50 minutes to realize them.

However, the consequence of implementing teaching methods like ecopolicy® in a wider field should not be a shortage of the learning matter. Ideally, systemic learning methods should be included into lessons rather than to require extra time. The teacher from Salzburg summarized it the following way: "The most important factor for changing the system is the teacher himself. When the teacher is determined, when there is a good reason for him to use these teaching methods, when the teacher gets instructions, propositions, how to prepare the method didactically and how to use it in the best way, then change is possible. Ecopolicy® is planed so perfectly that it can be implemented directly in many subjects. There is just the need to see which topics from curriculum can be used. […] What we need now, is the teacher to be motivated. Children are already motivated, they are happy about some variety in the lessons, they are happy to learn in a reasonable way. […] Therefore it is necessary to make it easier for teachers to break their habits. […] You can not do much from above. The educational ministry can provide cybernetic learning methods, but can not force anyone to use them. Therefore the motivation has to be created!"

2) REFLECTION AND FURTHER IDEAS

2.01) The educational system in causal-loop-diagrams

We embedded the subject of system thinking in schools as part of the society by using three causal-loop-diagrams. The first one is the outer system, the other ones are subsystems.

In the following, not all reinforcing or balancing loops, but the most important interrelations have been described. Blue, continuous arrows without additional sign have depicted positive effects. Red, dashed arrows with a minus sign have depicted negative effects.

How can the educational system enhance the capability of system thinking?

Diagram 1: The impact of system thinking in our society

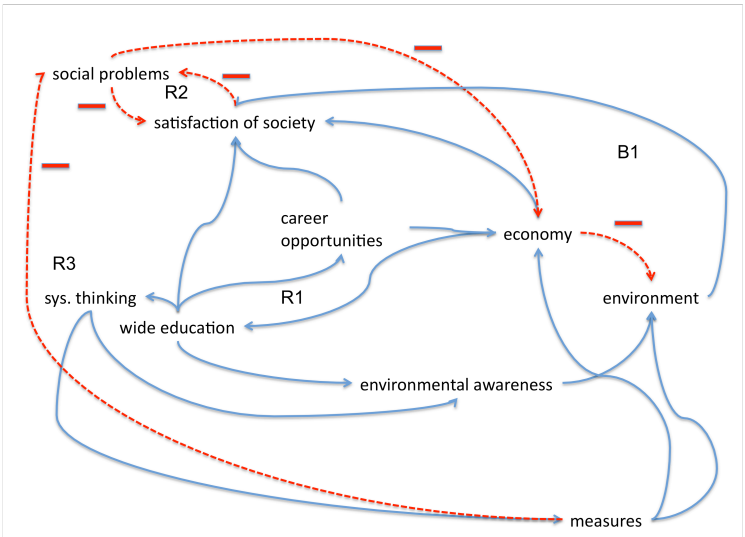

Figure 1 The impact of system thinking in our education

Description:

We start with the factor *wide education*. Often measures are only taken for higher level schools, here, we really mean all types of school, lower levels and higher levels. We assume that the more the educational system is enhancing system thinking, the better is the quality of *wide education*. Therefore *wide education* with good quality enlarges *system thinking* in society and *environmental awareness*, but also the *career opportunities* of the graduates and on the *satisfaction of society* in general.

Without concerning the factor *system thinking* the following loops are important:

Reinforcing loop R1:

The better the education is, the more the graduates have *career opportunities* and the more knowledge they can bring into their job. This is enhancing *economy*. Of cause, *economy* is effected by a lot of other factors, too, but in this diagram we left them out. The better *economy* is prospering, the more financial resources there are for the state government to invest again in a *wide education*. This of cause depends on the decision of politicians.

Balancing loop B1:

The more *economy* is prospering, the better is the satisfaction of society, in normal cases. On the other hand, through use of natural resources and pollution, which is still the accompaniment of economic growth, the *environment*, and through this, the *satisfaction of society* are effected negatively. When satisfaction of society is decreasing, social problems arise which has an negative effect on *economy* again.

Reinforcing loop R2:

The bigger *satisfaction in society* is, the less *social problems* there are, and the more society is satisfied again. Unfortunately, in many countries this reinforcing loop escalates into the bad direction.

Concerning system thinking, the following effect arrows can be added:

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Reinforcing Loop R3:

The more society is thinking in a systemic way (factor *system thinking*), the more systemic *measures* are taken. These measures can be taken by politics, organisations or the economy and that means that these people undertake an activity while considering the systemic behaviour of their subject. The factors *environment* and *economy* are manipulated with positive arrows; *social problems* are affected with an negative arrow. These factors influence *economy* again. As said before, *economy* has important effects on state budget, and therefore on the basic conditions in *wide education*. The better the financial situation in *wide education* is, the more capacities can be used to enhance *system thinking*.

Many time delays have to be considered: *Wide education* effects *environmental awareness* in society, *career opportunities*, *satisfaction of society*, and especially *system thinking* in society when the kids become adults, that means around 10 to 20 years later. This has to be remembered while trying to embed system thinking in educational system.

Diagram 2: The linking between the different educational steps

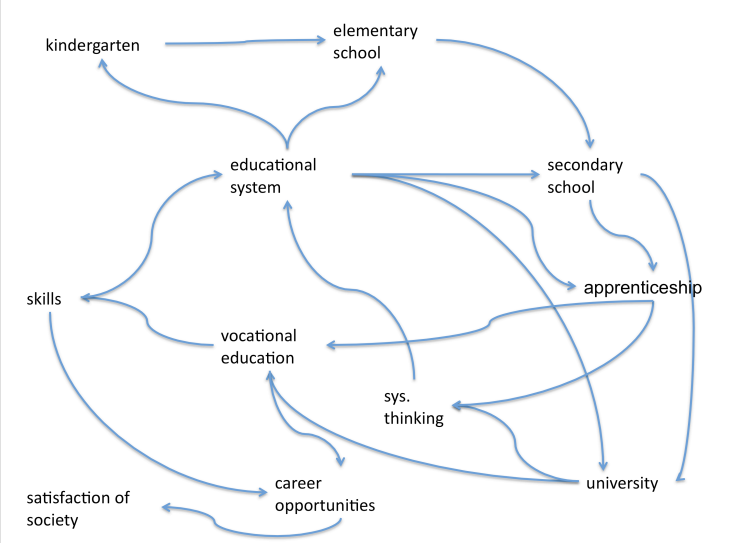

Figure 2 The linking between different educational steps

Description of diagram 2

The second diagram describes the subsystem of the factor "wide education" from diagram 1 and in addition to this it shows how the factors affect each other under the perspective of system thinking. This diagram should not be seen as a typical causal-loop-diagram rather as a general description of effects. All the arrows depict more or less "the more ... the more..."-relations.

First main loop: The ability of system thinking among the people designing educational system positively effects the level of system thinking in *kindergarten*, *elementary school*, *secondary school*, *apprenticeship* and *university*. This concerns all involved people and especially pupils. Additionally, when kids already train to link different subjects and think in interrelations in the beginning, this ability affects each of the following educational steps. This chain from kindergarten to elementary school, secondary school and in the end to apprenticeship or university has a positive impact on the capability of system thinking in society; see factor "*sys. thinking*". The more people in general think in a systemic way, the more *educational system* will be designed in a systemic way, too.

Second main loop: The general quality of degree of the *apprenticeship* and of *university* are summarised in the factor *vocational education*. This quality is not concerning the grade but the real capabilities of the graduates, which mean knowledge, social and personal competence and the capability of system thinking. With a time delay, this factor affects the *skills* of the whole

society. Here as well, the *skills* are defined as knowledge, social and personal competence and the capability of system thinking. With the factor *skills* effecting *educational system* and through this *apprenticeship* and *university*, the second main loop is closed.

The better the *vocational education* is and the better the *skills* of society in general are the better *career opportunities* there should be for each graduate. This factor affects the *satisfaction of society* positively. On this way, the second diagram is connected to the first one.

Diagram 3: The effect of system thinking in school:

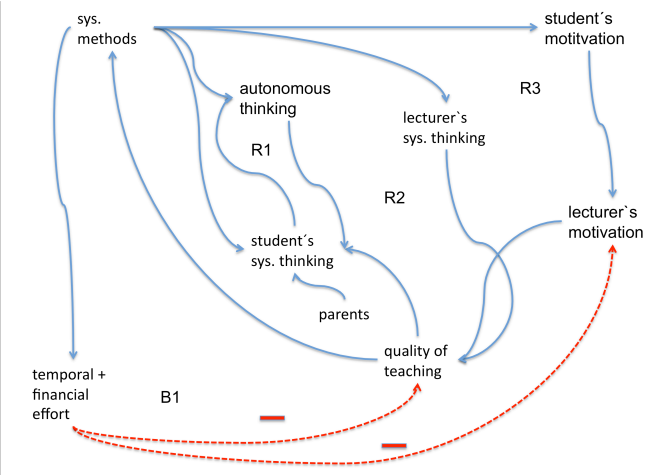

Figure 3 The effect of system thinking in school

The last causal-loop-diagram deals with the direct implementing of learning methods ^for system thinking. The two main factors that have a positive effect on *student's system thinking* are the adequate methods to train this way of thinking (factor: *sys. methods*) and the *autonomous thinking* of students. It should not be forgotten, that *parents* influence the way of thinking of their kids very much, although parents are not part of the official educational system.

Reinforcing loop R1:

With the factor *student's system thinking* affecting the factor *autonomous thinking* positively, and wise versa, the first reinforcing loop can be seen.

Reinforcing loop R2:

In order to bring system thinking into education, lecturers themselves have to learn it first. The more lecturers think in a systemic way, the more they can enhance the *quality of teaching* and the more they can integrate methods for system thinking into it (factor *sys. methods*). The more *system thinking methods* are used in lessons, the more the factor *lecturer's system thinking* is improved again.

Reinforcing loop R3:

According to the examples, described in the first part of the paper, it can be said that the more *system thinking methods* are used in lessons, the greater is the *student's motivation* to learn. When students are motivated, *lecturer's motivation* is increased, too. This has a positive effect on the *quality of teaching* and therefore back on the use of *system thinking methods*.

Balancing loop B1:

The more *system thinking methods* are used, the bigger is the *temporal effort* of each lecturer and the *financial effort* in general, e.g. for new learning material or to adjust the temporal effort of the lecturers. The bigger the *temporal effort* of lecturer's due to the new teaching methods is, the less time they have for their remaining tasks, therefore, from a certain critical value, the *quality of*

teaching starts to decrease. In addition *lecturer's motivation* sinks with increasing temporal effort. The decrease of these two factors effects the use of *system thinking methods* negatively.

Impact from outside:

There are two main factors to influence this system from outside: *lecturer's system thinking* and *temporal and financial effort*. As soon as a good way to train the lecturer's system thinking has been found, this ability is reinforcing itself in the loop R2. This training means another temporal effort for lecturers. Therefore, necessarily, the factor *temporal and financial effort* has to be influenced on the same time, which can happen by financial support by state and by sponsors and a better structure within schools and the other educational institutions.

2.02) How to enhance system thinking in education?

In the following description we concentrate on the higher school education, the Gymnasium, as it is called in Austria and Germany. We collected ideas for the different steps of education, which we went through ourselves: Kindergarten, primary school, secondary school and University. We did not describe any ideas for vocational schools and other ways of education. Of course this does not mean, that these types of schools do not need any modification.

2.02) a) Short summary

Enhancing system thinking is possible through game-like and computer-aided learning methods, whereas students develop the knowledge by themselves. In addition to the – still existing – normal lessons and interdisciplinary lessons, practical trainings and projects can take place that are organized by teams of pupils. All of this will be supported and supervised by teachers or older students, who teach younger students the necessary modelling and organizational competences.

2.02) b) In detail

2.02) b) i) Kindergarten

Of course it is not that easy to integrate system thinking into the kindergarten, but we thought of some pedagogical methods: Most important is to combine the different toys, which means that there should no longer a division between handicraft and the doll's kitchen for example. Further on the children should play games, which show how one thing is affecting another one, e.g. a kind of pendulum. In addition to this it is of great importance to appeal to the parents and kindergarten teachers to Answer the questions of the children! Children often ask why-questions. When this curiosity for background understanding is preserved, it should be easier for young people to understand complex systems.

2.02) b) ii) Primary school

I have to repeat myself but it is very important that we do not begin to separate into different subjects. This must not mean that we loose anything of the learning matter. There should be basic subjects: mathematics, the mother tongue and natural studies. The physical and the creative education should be included in all subjects and should no longer be seen as subjects for their own, because it furthers the learning process if you do not only sit at your table while learning. Not to forget that there exist different learning types among students and all of them should be furthered. Another focus should be set on working on interdisciplinary projects during school time. Moreover, social competences should be furthered, because it is important for group works and further on for interdisciplinarity, which represents the basic for system thinking. Of course, cybernetic games on a higher level than in kindergarten should be included in daily teaching methods.

How can the educational system enhance the capability of system thinking?

2.02) b) iii) Gymnasium

Basic structure

From outside to inside: Interdisciplinary projects with practical orientation should be a fix teaching method. In general the comprehensive school should no longer be divided into different schools when the children are ten years old. Instead different groups of performance should be introduced: That means that each student can be in different groups according to his knowledge in various subjects, this affirms that each student is furthered in the best possible way. The three different classes should only be offered between the age of ten and fourteen. Which means that the distinction concerning the performance, the level of the students is the same as now, but the difference is that all attend the same school. It is better to support different talents of students and especially to enhance the respect for diversity than to punish them for their failing. As a presupposition the education of teachers concerning system thinking, methods and interdisciplinarity must be furthered! The key for good education is the motivation of the teacher. Further on it is also important that the teachers get feedback about their way of education, on the one hand from the students and on the other hand from an adult, who comes to the class (and the teacher does not know the exact date!)

Interdisciplinary learning – The general Structure in four points:

- Different school subjects, but connecting this subject to others during the lesson by interdisciplinary exercises
- Time in school for interdisciplinary group-work on a project and internships
- Interdisciplinary lessons (e.g. accompanying the project),
- Teaching younger kids by older kids

The cooperation with the world outside the school through projects and internships should be brought forward: For example simulation of working life, maybe in local firms, simulation games, as well as practical trainings in different jobs. This has already been realized in many schools. The goal of these teaching methods is to help to connect the learned stuff with the practical application. In general, the older the students get, the more choices they should have:

- From the age of 10 to 14 years: mathematics, the mother tongue and one further language must be learned. In other subjects kids can choose their profile, but in general all the subjects are mandatory. Pupils can choose their level of difficulty.
- After the age of 14: There should be a setting of priorities: The general education must be guaranteed as well. Therefore a minimum of hours in each sector (natural studies etc.) must be taken. This system is already used for 17 to 19 year old students in German schools.

A problem occurs here: In order not to destroy the community in class too early, pupils should always learn in the same form until the age of 14. After that, there is one part of school time in class, one part of time with an own timetable (with core subjects and one part for group-work on an own interdisciplinary project. We think of two different types of projects: working on interdisciplinary projects alone and working on interdisciplinary projects in a group. Further on we want the students to work on self-chosen topic for half a year, but of course only for a part of the school time e.g. 20%. Here it is important to notice that self-organisation must be learned as well. There should be one subject called social competence, where topics like project

management, research, presentation techniques, group dynamics, etc. are taught.

Further more pupils should learn to understand the school system itself: Therefore it is useful to implement more democratic elements in school, e.g. children's-parliament etc. That should make pupils understand, how their own decisions influence school life. This is easier to realise in smaller schools.

As mentioned before, pupils from higher levels can teach pupils from lower levels. The advantages are that there is less division of pupils into lower or higher "education classes". Pupils of higher levels can deepen their knowledge through teaching others (that means less work for teachers). On the other hand these young teachers perhaps do not teach the right information, or maybe just confuse pupils, because their way of explication does not fit to the teaching methods of the real teachers.

Summary

All in all, the time in school should be divided into three main parts: Firstly, time for common subjects like mathematics, mother tongue, physics, music... with interdisciplinary teaching methods. Secondly time for interdisciplinary subjects and thirdly time for a auto-organised work on an interdisciplinary project.

Learning methods in class

There should be at least one cybernetic learning method used in each subject:

- Games: e.g. role-playing game – games like "a school transformed into a state" for a better understanding of politics.
- Computer based methods, e.g. Consideo®-Modeler software or Ecopolicy® (In Bavaria, Germany, there is already an initiative to include the modelling software "Consideo®-Modeler" in lessons.)

Further more we want to integrate physical and creative elements in all other subjects. This is similar to primary school, except the point that there are also music lessons or art lessons for interested students. In addition, learning in self-organised little groups, with self-chosen topics must be enhanced.

In General:

The basic idea is to learn associatively: While teaching, teachers should always connect new information to something known. This method is already used in the school. Teachers should animate pupils to create these connections by themselves.

Another very important point is furthering social competences. The implementation happens through interaction in the classroom, an own subject, organisational activities in the project group or student-parliament.

Especially in gymnasium it is a basic skill to learn that there is not „one truth", but many mental models. Students should deal with the topics critically, and see the information as a mental model of some scientists, which also can be falsified some day.

As a conclusion we want to summarize: Developing autonomous and critical thinking and personal responsibility: When pupils always get told how to interpret a certain complex system, they will not be able to do so by themselves. Of course teaching methods have to be adapted to

the age and level of development of the kids and teens.

Further more there must be more of "trying to understand" than of "learning by heart" in our everyday school life. The disadvantage is that it takes more time and needs motivation in the beginning. Nevertheless. The advantage is represented by the proven fact that knowledge stays longer in your mind and can be transferred to other subjects – On the other hand, most of the facts, we once learned by heart for an exam have been forgotten the next day.

2.02) b) iiii) University

The basic structure should include a core subject like in the example "Environmental System Studies". In general we would suggest a double study, which consists of system sciences and one other subject, which can be chosen from the students by themselves. This guarantees a good interdisciplinary education as well as the basic knowledge, on the level of a Bachelor- degree in one other subject. This education step should last for three years and in the end the student should have a bachelor. (Such a system already exist at some universities in Germany)
In the fourth year at university the students should gain skills from two other subjects, these should match to the one chosen before in the bachelor. Of course a commission, which acknowledges the intentions and selection of subjects, must be established.

Afterwards there should be one year in which the students have to write their master thesis including on the one hand system sciences of course, as the basis, and the three other chosen subjects. The year before should be seen as some kind of preparation work. In the end the degree should be a master title.

In detail, students should learn how to learn and again, that there is not only one "truth" but most of the time many mental models, which try to describe the reality. Further on we want to bring more of "trying to understand" than of "learning by heart" into our universities and it is also important to link the old knowledge with the new one.
But in this educational step there should be more focus on research and projects, which teach the students how to manage and to cooperate with others.

2.02) c) Important points for implementing these ideas into our educational system

Remembering our own school time, we outlined some important points, which should be considered while implementing these ideas into the educational system:

- When pupils are not interested in the subject, group work and so called self-organized work often leads to frustration. Therefore it is important to influence the learning motivation of the pupils by letting pupils choose their own team or own topic for the group work. Furthermore, school can provide other incentives, e.g. competitions...

- Aspect of reality: It is important to tell pupils how they can use their acquired knowledge in real life, e.g. in a job or in further education. Our own experience showed for example that many pupils complain about mathematics - they never need it in real life and still have to learn it. On the other hand, mathematics are part of most of studies at university.

- Working on a project: In contrast to the skill of system thinking, self-organization is not inborn. Therefore, pupils have to learn it, firstly. Excellent mentoring and good preparation by a subject called "social competences" are necessary.

- Despite of all the extra activities, there should be a sufficient basic education in the subjects mathematics, mother tongue, foreign languages and natural sciences . Still, a good

solution has to be found for this.

- When every pupil can choose his or her own core subjects, this is very complicated to organize. In Germany it works well for two grades. For eight grades, as proposed above, still a good solution has to be found.

- Teachers' experience showed: In order to learn system thinking you must do training. Therefore not only an interconnected school structure(as depicted) is needed, but it is especially important to use simulation games, exercises for modelling and other concrete training methods in class.

- Last but not least: Learning methods have to be fun, as often as possible, because having fun is the best motivation to learn.

Altogether the described picture of a changed educational system should not be seen as a complete and finished plan, but rather as an impulse for further development.

Conclusion

Four points, how the educational system can enhance system thinking:

- Connection to reality
- To connect areas that were divided before: different subjects, different school types...
- Playful, optionally computer based learning methods
- Most important: To enhance autonomous thinking and acting of the pupils!

Explication

- In order to understand a complex system, a person must be able to think autonomously. People, who just repeat information learned by heart, never will be able to see through complex systems.
- Today's society needs this way of thinking. Only people, who think in an autonomous, critical and systemic way, will be in a position to overcome a deadlocked mindset and behaviour. Exactly in this way, we need to get to a sustainable way of living.
- The autonomous way of thinking can be reached by using the already explained learning methods.

There is one point, which is much more important than using these teaching methods and this point will probably meet much bigger resistance: It is the change of thinking by all involved people. Still, way too many teachers expect from pupils stupefying learning by heart a lot of information. Not until the people who design curricula and educational system in general will acknowledge the importance of system thinking, teachers can realize cybernetic methods and an adequate pedagogy in school.

Our answer how to enhance system thinking: An autonomous way of thinking through adequate learning methods and a change of mind of all involved.

How can the educational system enhance the capability of system thinking?

3) OPEN QUESTIONS

In the end, we have one question for further discussion: There are already many methods and material to enhance system thinking in education, as our four described examples (see above) show. How can this material and methods be used in a wider field in kindergartens, in schools and universities? With what kind of difficulties we will have to deal on this way? How can we overcome these difficulties?

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