The Learning Environment as a Chaotic and Complex Adaptive System

E-Learning Support for Thrivability

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Abstract: Thrivability is a novel concept describing the intention to go beyond sustainability, allowing a system to flourish (Russell, 2010). For a society or organization to be thrivable, educated, responsible acting agents are needed. Traditional education focuses on (efficient) reproduction of existing organised bodies of information (Dewey, 1938). We argue that complex adaptive systems theory and chaos theory provide concepts well suited to inform the design of learning environments, in order to facilitate a thrivable organization. This learning is not linear and externally controlled, but happens in a chaotic, yet guided manner. After discussing the suitability of the theoretical body of these general approaches, we show how a concrete progressive education approach, called the Dalton-Plan pedagogy (Parkhurst, 1923, 2010), implements and supports these elements. By doing so, we show that the Dalton-Plan pedagogy is well suited for education of agents working in and for thrivable organizations. Support for teachers as part of this evolving learning system is provided by an e-learning environment.

Keywords: progressive education; dalton-plan; chaos-theory; complex adaptive systems; e-learning; thrivability

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1 Introduction

Sustainability focuses on system resources and their consumption with a focus on keeping a system productive over time. Thrivability includes all aspects of sustainability, but additionally goes beyond sustainability by including aspects enabling systems to grow (organically). The concept of thrivability is currently not well defined in scientific terms (Russell, 2010). However, with respect to knowledge and learning, the difference between sustainability and thrivability may be identified in the following way: For knowledge acquisition in terms of sustainability, reproduction of knowledge is sufficient, as this maintains the system as it is. For knowledge acquisition in terms of thrivability, the generation of new knowledge is required. In order to facilitate thrivability of social-systems (e.g. organizations, the overall society), the agents that are the building blocks of these systems have to be considered. To support thrivability, these agents need to be able to act self-organized towards an uncertain future, and within a dynamic environment. Organizations and societies aiming at the generation of innovative solutions, require agents (people) with creativity, scientific thinking, and critical thinking skills, able to evolve the knowledge on which organizations and society is more and more dependent (Rocard et al., 2007). However, approaches are needed to teach people self-organization, creative and critical thinking.

Content-driven teaching in traditional classroom lectures promotes passive learning, and fails to support students to acquire creative problem-solving and critical thinking skills (Biggs, 1999; Marjanovic & Bandara, 2011). Dewey (1938) criticizes these traditional, but still predominant educational approaches, where text books are the chief representatives of the wisdom of the past. These approaches assign teachers the role of a keeper of the truth through whom knowledge is communicated. Such education requires students' attitude to be one of “docility, receptivity, and obedience” (Dewey 1938, p. 18). This type of learning prepares students for situations described by teachers and their text books, but not for an uncertain future where technologies are used, and problems solved, which are both unknown today (Fisch et al., 2012).

In the following a concrete approach, facilitating learning of agents, enabling them to facilitate thrivable systems is discussed. The perspective taken in this article is through the lens of chaos and complex adaptive systems theory. We argue that, by making use of theoretical aspects stemming from these theories, a learning environment may be designed, which enables learners to acquire necessary skills, allowing them to head towards an unforeseen future. We additionally show a concrete learning environment, facilitated by e-learning technology, to support learning along these theories.

2 Complex Adaptive Systems, Chaos Theory, and Learning

“We may reject knowledge of the past as the end of education and thereby only emphasize its importance as a means. When we do that we have a problem that is new in the story of education: How shall the young become acquainted with the past in such a way that the acquaintance is a potent agent in appreciation of the living present?” (Dewey 1938, p. 23)
With respect to learning, we see the living present as a complex and chaotic environment. Learning and teaching today aims at preparing students for jobs that don’t yet exist, using novel technologies, not yet invented, in order to solve problems unknown today (Fischer, 2012). In the following we describe complex and chaotic systems theories, their properties, and aspects of these types of systems. These aspects and properties are linked (bidirectionally) to learning. In the context of this work it is assumed that students should be enabled to solve problems, in a self-organized manner. By focusing on the overall learning system (or learning environment), the content and the size of these problems are intentionally left open.

Chaos Theory and Complex Adaptive Systems Theory discuss similar properties of systems, but following Norman (2011), these theories may be differentiated, in order to pinpoint important properties.

A system is chaotic, if it contains non-linear relationships between its parts. Its global state is to a large extent unpredictable. For this type of system, it is sufficient that simple, but non-linear relationships between a few variables (parts) exist.

A system is called complex, if it contains non-linear relationships between many parts that interact in unstable and unpredictable ways. A complex adaptive system additionally has active elements (called agents) that interact in a self-organized manner. The overall system state may not be determined by the sum of these individual agents’ behaviors.

Both types of systems share a few properties. Both exhibit non-linear and emergent, non-deterministic global behavior. For the analysis of such systems, not only the parts are of relevance, but also the interaction between the parts.

2.1 Chaos Theory and Learning

For a system to be called chaotic, it must be a continuously dynamical system, with its future state not being predicable but evolving over time (Trygestad, 1997; Davis et al., 2008). In the following we identify properties of Chaotic Systems and bridge the gap to learning and teaching. These properties make chaos theory suitable for using as a paradigm for building a thrivable learning system, as it’s impossible to predict the conditions based on which a system becomes thrivable.

2.1.1 Dependence on Initial Conditions

Often quoted in chaos theory, is the butterfly effect coined by Lorenz (Hite, 1999; Gleick, 1987). In this theoretical example a system's state evolves unpredictable over time, depending on small changes somewhere in the system. In that particular example, a small change in the flow of air caused by a butterfly's wing, over time results in significant differences in the weather’s behavior, in some other part of the world.

With respect to learning, subsumption theory states that learners do not start empty minded, but have a wealth of personal experiences and existing skills, to which a given content needs to be connected for meaningful learning (Ausubel et al., 1978). For teaching to be successful, these individual preconditions need to be taken into account. This is in line with the views by progressive education, emphasizing the need for student centered education (Aqda et al., 2011).

2.1.2 Self-Similarity and Fractals

Self-similarity is a property, for example found in fractals, where a system is similar to a part of itself. Learning happens on various levels, and similar patterns emerge on different scales of understanding (Trygestad, 1997; Hite, 1999).
Learning may occur in a single student, within a group of students, and within the overall class. This may lead to situations, where during stable periods (e.g. on class level), qualitative leaps (in contrast to gradual change) on a lower level (e.g. individual level) may occur. Of course, also the other way around is possible (see Bifurcation in the following). This is called “scale invariance”, or fractal dimension, of growth (Eijnatten, 2004).

In organizations, fractal dimensions of learning are sometimes expressed as “values” or “vision” (Hite, 1999). Understanding the fractal dimension a consistent view on an organization may be developed. This in turn allows better understanding of contributions of agents, or a group of agents to the overall organization (Hite, 1999).

2.1.3 Strange Attractors
In a dynamical, often chaotic system, a (strange) attractor is a point, towards which, or around which, particles (parts) of a system are moving. Particles getting close to the attractor remain close. However, the ways along which parts are moving are not fixed or predetermined.

The interactions in a group of learners, or the line of thought by an individual, may be viewed through time- and phase-space. There may be points around which the discussion or argument cycles. These points (or strange attractors) can take many forms like ideas, theories, and approaches to a solution (Davis et al., 2008).

“Although two classes may discuss the same oil industry, the strange attractors can certainly be different, the basins of similar attractors can be different, and certainly the points of discussion will not only be unique to the class but to the individual; that is, chaotic in nature and unpredictable… While the global nature of the discussion … and certain basins of attraction may be predictable, that is, global stable, there will be, in the individual points/comments around these basins ‘infinite modes, infinite degrees of freedom, infinite dimensions’.” (Davis et al., 2008, p. 17)

As there is, potentially, an infinite number of people, who may take up existing (published) lines of thought, the phase-space may hold an infinite number of thoughts (Davis et al., 2008). Attractors in the classroom facilitate individuals, groups of learners, and the overall classroom, to arrive at a limited set of conclusions.

2.1.4 Bifurcation
Bifurcation occurs when a small change in a system causes a dramatic change in its overall behavior. The concept of bifurcation is shown in the following figure (Hite, 1999, p.97). It illustrates a system's transition over time. On the left the system is in its beginning state. It exhibits a single steady state. The branches illustrate a period in which the system begins to fluctuate around two, and in the following more states. As multiple bifurcation points show, system parts are attracted by more and more forces, and the system is getting more complex over time (Hite, 1999).
With respect to learning, the theory of threshold concepts provides such elements of change. Threshold concepts are conceptual gateways to learning in a discipline (Meyer and Land, 2005):

“...attempts to characterise such conceptual gateways it was suggested in the earlier work that they may be transformative (occasioning a significant shift in the perception of a subject), irreversible (unlikely to be forgotten, or unlearned only through considerable effort), and integrative (exposing the previously hidden interrelatedness of something).” (Meyer & Land, 2005, p. 373)

Examples of such concepts are, “precedent in Law, depreciation in Accounting, the central limit theorem in Statistics, entropy in Physics” (Meyer & Land, 2005, p. 374). These threshold concepts are bifurcation points, which once understood, transform the learners understanding in a significant manner.

When a student group is discussing a certain topic, the discussion may circle among two or more concepts (the system fluctuates around two or more states). By introducing a threshold concept, the teacher interferes with the discussion. The discussion will evolve into something different when this concept is taken into account. However, it can't be predicted, if the discussion starts focusing on that single concept, and a conceptual gateway is opened (as briefly described above), transforming the understanding of the participants into something new. Referring to the figure above, it is not predicatable if the “system” moves to the left or right side of the figure.

2.2 Complex Adaptive Systems Theory and Learning

Complex Adaptive System (CAS) Theory is concerned about agents that exhibit self-organized behavior. The agents and the overall system is capable of adapting to its environment. However, there is some non-linearity in the system which does not allow predicting the overall system's behavior over time (Holland, 1996).

The following figure illustrates a Software Multi-Agent System, and shows how a solution is communicated between the agents (the nodes). This system highlights several aspects of a CAS.
On the first picture only the agents are shown, no lines are drawn, as no communication has taken place between agents. Then, a few agents start to communicate (lines appear). Agents at upper rows of each image divide the overall problem into smaller parts, and communicate these parts to agents on the next row down. Agents on the bottom send partial solutions back. The black rectangles show these possible solutions. As can be seen, the agents consider more and more alternatives (the rectangles get longer). But some of the solutions are discharged immediately, or are discharged after receiving a “no-go”, from the agent to which the partial solution is sent.

Agents that receive partial solutions try to put these partial solutions together and evaluate these. Some of the solutions can then already be discharged. If a solution is found, it is sent again to an agent on a higher level. By using a nested way of problem decomposition and solving, each agent solves a pretty small problem, but still an overall solution to a very large problem can be provided.

Figure 2: Emergence of a solution in a multi-agent system (Weichhart 2008, Karageorgos et al. 2003)

2.2.1 Active Agents

In a complex adaptive system, “great many independent agents are interacting with each other in a great many ways” (Waldrop, 1992, p. 11). The agents themselves may follow simple rules how to interact with other agents. This interaction is happening locally between individual agents, or agents and their environment. There is no global control flow.

Social learning facilitates self-directed learning, by providing approaches needed to learn in novel situations (Bandura, 1989). In a learning environment populated by active agents, learning processes may be influenced by the environment, the behaviors of agents and the individual agents themselves. These factors influence each other, leading to social dynamics influencing the cognitive dynamics (Bandura, 1989). For example, agents may
change their behaviors when observing how peers solve problems. Teachers have to take care when designing the learning environment in order to facilitate the interaction between the agents, in order to allow social learning (Stary & Weichhart, 2012).

2.2.2 Self-organization and Emergent Behavior

The lack of global control enables the agents to act self-controlled and self-organized. The interaction is locally controlled by the participating agents. In a social system the learner’s behavior influences the environment, and bidirectionally the environment influences the learners (Bandura, 1989). Local interaction, with or without taking the higher system level state into account, facilitates emergent behavior on the higher system level. The global organization of the system "naturally emerges out of the interaction of individual agents without any top-down control" (Engelhardt & Simmons, p. 41).

This can be observed on multiple levels, where for example the interaction of brain-cells influences the behavior of the learner, and interaction between learners influences the behavior of the class (Holland, 1996).

Individual and group learning paths, and learning results, are not predictable. The performance of a group does not only depend on individuals, but also on the interaction between individuals. Emergent learning takes place, and through multiple qualitative leaps on lower levels the overall system develops (Eijnatten, 2004).

However, agents have to learn to self-organize their learning. Meta-learning (learning about one's learning) is necessary. Yet, allowing agents to follow their own learning paths opens the potential of a diverse set of (innovative) learning results.

Overall, through the lens of Chaos Theory and CAS Theory, a learning environment is where stability exists near instability, and creative chaos may come into existence. This leads to indeterminate solutions, with respect to what is learned and when. Learners build up experience and adapt their behavior, which in turn leads to adaptation on higher system levels.

3 Learning and Teaching

In the previous section references to learning from Chaos Theory and Complex Adaptive Systems Theory have been made. In the following a learning approach is discussed and related to the other body of theory. By this we intend to establish a connection between two separate bodies of theory.

3.1 Progressive Education

The different pedagogical approaches, which are belonging to the class of progressive education approaches, share some common principles that support the acquisition of creative problem-solving, critical thinking; practical application and social learning skills (cf. Davis et al., 2008; Aqda et al., 2011; Stary & Weichhart, 2012; Skiera, 2004). Common (core) properties of progressive education approaches are:

- situated, complex, challenging problems are used, to allow learners to individually explore the problem space using authentic activities;
- cooperation and social learning are inherent parts of problem-solving and knowledge acquisition;
- teachers are facilitators of learning, providing a motivating environment.
- responsible learners are actively engaged using individual learning strategies;
Progressive education puts the student in the centre (Eichelberger et al., 2008). Learners (students) are supported in actively acquiring knowledge and skills in a self-organized way. Progressive approaches to education let students follow their own learning paths when acquiring new knowledge. Dewey states that “the ideal aim of education is creation of power of self-control” (Dewey, 1938, p. 64), and therefore education requires responsible and active learners. This in turn requires students to be able to actively manage their own learning paths. Students need to be able to reflect their own learning in order to make this effective.

Also, due to today’s pace of change, self-regulation is becoming increasingly important. Knowledge is quickly outmoded; for being able to sustain growth, learners need to update their skills permanently (Bandura, 2001). The acquisition of knowledge (i.e. the process) is more important than soon outdated content (Quinton, 2010).

In order to become acquainted with the process, problem solving tasks are needed. Learners should be required to apply critical thinking, divert thinking and putting their knowledge into action. These abilities are key-factors for a high-tech industry, in a knowledge society, and hence for (economic) growth (Rocard et al., 2007). The process of learning also has an important social dimension. Really complex and challenging (learning) goals are not reached by individuals but require cooperation. However,

“[a] group’s attainments are the product not only of shared knowledge and skills of its different members, but also of the interactive, coordinative, and synergistic dynamics of their transactions.” (Bandura, 2000, p. 75)

Teachers need to relinquish control, and are highly involved and active together with the students (Davis et al., 2008). They are required to plan and provide a motivating learning environment. Another important aspect for teachers in progressive education is that they take the role as facilitators of self-organised groups of learners. Teachers as facilitators to learning are expected to usually learn more than to teach (Dewey, 1910, 1997).

3.2 Dalton-Plan

The Dalton-Plan is a specific progressive education approach, created by Helen Parkhurst (1923). The overall goals of this approach are to support learners to learn handling and managing freedom, learn creative problem-solving, learn to cooperate in groups (Eichelberger, 2008).

In this approach, two major instruments are provided to structure the interaction between learners and teachers. The first instrument is the assignment, used to provide a describing-structure guiding learners through their process of knowledge acquisition. The second instrument is the graph method, used as a graphical feedback to have teachers and learners understand all learners’ progress and current state, while learners are working alone or in smaller groups on problem-solving and knowledge acquisition activities.

3.2.1 Assignments

Assignments present the motivation why learners should work on an assignment, objectives of the learning task, and the structure of the work to be done and provide deadlines as well as meetings, in which individuals and groups present their (preliminary) work. Following general progressive education principles, assignments should be motivated by real-world application contexts. Learning tasks, which at the end produce documents (i.e. written or documented work), guide the learning process while keeping the result open. Assignments
need to make it clear that it is the learner's responsibility for the outcome. However, assignments facilitate the individual problem-solving strategies and do not determine the learning paths. Care has to be taken when writing assignments that these only set learning goals, but do not determine the process to reach these goals.

To be able to guide the process, interactions between learners themselves and between learners and the teacher need to be planned. This includes for example meetings for which learners prepare preliminary results and present it to a group. For better understanding of the current state of the overall system, feedback graphs are used. These support ad-hoc meetings for guiding learners based on their current stage in their learning process.

In the following the structure of a Dalton-Plan assignment is presented (Parkhurst, 1923, 2010). The assignment is divided into multiple sections. Below a description of the different sections is given, followed by an overview figure showing the interdependencies between parts.

Preface: This section should provide an emotional and content-wise motivation (interest pocket), answering the question why an assignment should be done and should also motivate learners to do the assignment. Motivating for learners may be, for example, challenging tasks, or videos, about the given topic.

Topic: This section clearly states the aspects of a general subject which the assignment helps to understand.

Problems (Tasks): In this section the general tasks to be accomplished should be given. This section therefore includes the objectives to be reached by the learner. The types of tasks should range from reproduction tasks to problem-solving tasks – (Rozendaal, Minnaert & Boekaerts, 2001). Problem-solving tasks should be challenging and require collaborative work in order to be motivating to learners (Bandura, 1988, Reich, 2008). The development of problem solving skills requires learners to acquire and use analytical, creative and practical abilities (Aqda, 2011).

Written Work: In this section all documents produced when working on the tasks should be stated. This includes for example, essays written and concept maps created. Documents may be produced by individuals or by groups of learners. Learning tasks should provide room for groups of students to explore and discover new knowledge (Reich, 2008). The problems and written work section should only guide learners through an indicative structure. It would hinder self-organized problem-solving activities if too much (content-wise and process-wise) is given in advance (Stary & Weichhart, 2012).

Memory Work: In contrast to the previous section, here only individual work can be given. This section makes the cognitive work of learners explicit. In this section threshold concepts (see below) might be mentioned explicitly. Examples for this section are: “Provision of constructive comments and feedback”, “Poems learnt by heart”, “Understand the concept of X”.

Conferences: Meetings should provide the learners the possibility to present their work. These meetings should have an objective, a date and a place. It should be clearly stated, what is to be discussed or presented at each meeting.
References: In this section literature useful for acquiring required information in order to accomplish the tasks should be given.

Equivalents:

“Here it is essential to show a pupil how to record his progress on his own contract graph, for it is a picture of his accomplishment and a compass which enables him to discover and satisfy his needs. His graph should be taken from laboratory to laboratory and to all class conferences. It is his ticket of admission and should be accurately marked, daily as he goes on. It is the psychological picture of his job. Except on rare occasions he does not do all the month’s or even all the week’s work at a sitting Thus, if in any one week’s assignment grammar, translation, and oral work are required, say, in a foreign language, a time equivalent should be stated. Grammar, for instance, might count as two days’ or units of work, translation as two days’ work, and oral reading as one day’s work. In a monthly assignment, when the subject is English, his review of the book in question might count as reading, one week’s work, and the written part as three weeks’ work.” (Parkhurst, 1923, p. 69)

Bulletin Study: Since learners work self-organized in groups, a place where up-to-date information is exchanged is needed and should be given in this section.

Departmental Cuts: Given the idea of learning using situated, complex, challenging problems (see above) it is possible that the work on an assignment accounts for multiple classes. Writing an essay for a (e.g.) “German-language” course could also account for work in “science education” depending on the subject given. In this section credits given for multiple educational “departments” are stated.

Figure 3: Dalton-Plan Overview

In the following an example assignment is given. The first column shows the Dalton-Plan section. This assignment is part of a set of assignments for a seminar for business information systems students. This assignment relies on the below presented e-learning environment and hence include hypertext links to other parts of the online-system marked this way: &lt;Link to ...&gt;
## Seminar: Applications of Communications Engineering – Business Information Systems:

### Assignment: Multi Agent Systems: Objectives, Methods, Tools

<table>
<thead>
<tr>
<th>Section</th>
<th>Content</th>
</tr>
</thead>
</table>
| **Preface:** | (a) Science is the "systematic and comprehensible investigation into any matter". Writing a seminar paper is a first introduction to making (discovered) knowledge explicit for other people.  
(b) A multi-agent-system is a software system in which active software components (called agents) communicate their knowledge, and pro-actively act on the information sensed in their environment. |
| **Topic:**   | Each group will analyze scientific literature about one of the following questions and prepare a seminar paper on the topic:  
* What are the objectives of multi agent systems (MAS)?  
* What types of methods are used by scientists to create MASs?  
* What tools (or technologies, libraries, frameworks, algorithms) are used by scientists for the implementation of multi agent systems? |
| **Problems and Tasks:** | a.1) Individual Student: Search the available scientific literature databases  
a.2) Individual Student: Analyze and select papers as input for your work  
b) Group Work: Share and discuss the selected papers in the forum.  
c.1) Group Work: Put together a paper that reflects the scientific structure of papers e.g. containing Abstract, Introduction, …. Conclusion;  
c.2) also take care of proper quoting referenced work  
d) Individual Student: Critically review your paper and propose |
| **Written Work:** | a.1) Create a table, documenting your searched, and selected papers from the literature database. Include documenting the reasons why you think this paper is worth the time reading and adds value to your seminar paper.  
b.1) Share this table in your group of authors.  
b.2) Discuss all tables and select references in the group.  
c.1) Prepare an outline of the paper in your group. Present this outline at the first meeting.  
c.2) Revise your outline if required and start writing your paper. It is left to the group how the work is distributed among members.  
c.3) Upload the paper in your online workspace.  
d) Document your review of your own paper in the forum. |
| **Memory Work:** | a) Understand how scientific literature is structured.  
b) Writing supports reflection and requires structure.  
c) What are MASs? |
| **Conferences:** | Wed. 4 → room 048: 14:00-18:00 → present your outline  
Wed. 25 → online: 23:59 → upload your paper in the e-learning environment  
Mon. 28 → online: 23:59 → feedback by teacher  
Mon. 4 → room 048: 15:00-17:30 → present your paper |
* List of available literature databases: [http://www.ubl.jku.at](http://www.ubl.jku.at) |
| **Equivalents** | 12h → [Link to View Graphs] |
| **Bulletin Study** | → [Link to Forum in e-learning platform] |
| **Departmental Cuts:** | -- |

*Table 1: Dalton-Plan Example Assignment*
3.2.2 Graph Method

“Graphs are, moreover, very helpful to a teacher in the choice of the right moment to offer special help or instruction to her pupils. If, for instance, she observes that several children have reached the same stage in their work on any given subject, she can give them an appointment to meet her together on the following day at a fixed hour in the laboratory belonging to that subject. These appointments should be posted on the student’s general notice board.” (Parkhurst, 1923, 2010, p. 138)

The following image shows two such graphs. In the background, a graph sheet for single teacher and a single class is given. Here the teacher sees the progress of all students for a single subject. The graph in the foreground shows the graph sheet of a single learner. It is used by the learner to see what needs to be done. In the Dalton-Plan pedagogy, the student may choose when to work on which topic. Hence she may decide to work on all assignments, with respect to a single subject, on the first day of the week and then progress to other subjects. The graph allows understanding how much work is still required for each topic.

The graphs provide feedback for planning of next steps. As such they give teachers and students an overview of the global learning progress.

![Graph Method Image](image)

Figure 4: Dalton-Plan Graph Method (Parkhurst 1923, 2010, p. 137, p. 143)

3.3 Dalton-Plan and Chaos Theory and Complex Adaptive Systems Theory

In the following we argue how the Dalton-Plan approach allows to facilitate complex adaptive systems and chaotic systems. This approach enables the education of self-controlled active agents capable of creative problem-solving required for thrivable organizations. The Dalton-Plan has been designed as an influence for learners (Parkhurst, 1923, 2010)
Dalton-Plan Assignments

The Dalton-Plan provides instruments to build an environment for active agents who are responsible for planning their own learning. Even more powerful, it facilitates, through the assignments, that active learners self-organize their own learning to reach the learning tasks set by the teacher. Assignments have to be designed to guide learners but not to determine results. Assignments include by definition cooperative work, and provide a learning environment within which learners (are required to) self-organize themselves.

Providing threshold concepts to learners in the tasks section, and providing a space for discussing these, allows teachers to introduce elements for Bifurcation. It may happen, but cannot be predetermined, that the discussion evolving around these threshold concepts will open the door for a deeper understanding of the assignment's topic by learners.

Not only the structure and content of assignments, but also the assignment's existence itself supports self-organization. The written form of assignments allows agents to work without direct intervention by teachers. Students take assignments with them, and have a point of reference for their work which enables them to work alone, or in groups. No direct supervision of the teacher is given by definition. In case that they make no progress working on the tasks, the assignments provide elements like the bulletin study section or the reference section where learners may find further help for their work. Additionally, the information provided in the conferences section of Dalton-Plan assignments informs students when and how to contact the teacher in cases where more guidance is required.

The assignment itself may serve as a Strange Attractor, allowing learners to refer to the tasks provided by the assignment provide the focus point around which discussions evolve. Assignments reinforce the need for learners to involve their personal problem-solving knowledge, which will make the learning outcome dependent on initial conditions. This requires teachers, working with the Dalton-Plan, to step back and let the learners construct their individual, personal solutions for a given tasks/problems section. The teachers' role is changed from “keeper of the truth” to “facilitator of learning.

Feedback Graphs

The required collaboration in groups facilitates learning on various levels, the individual level, the group level, and on class level. Here the graph method has shown to be of help. The graph method helps to visualize results of emergent behaviors resulting from these individual learning paths and the interaction in groups. Due to reached results documented in the Feedback Graphs, the state of an individual learner, or a group of learners is made transparent.

As stated by Parkhurst (see above), the bulletin study section is used to call for meetings with students that have reached the same point in their work on the assignments. This provides room for fruitful discussions around issues relevant for the upcoming work. This allows to facilitate local interaction between students.

Students that have not reached a certain learning result may understand whom to ask for further help. Feedback Graphs therefore facilitating local interaction by taking a higher system level state (a learning state met by a group of students) into account. Therefore the graph method helps to dynamically create groups of learners which are at the same stage when working on assignments facilitating the fractal dimension of learning. Feedback Graphs facilitate emergent behavior on the higher system level through local interactions.

As required by progressive education in general, an environment for active, self-organized agents is provided through the instruments.
3.4 Teaching in progressive education

While there is growing evidence that teaching based on progressive education and constructivist pedagogical principles does work,

“one of the critical issues is faculty development, helping teachers to become familiar with new approaches to teaching and helping them gain experience actually implementing them” (Michael, 2006, p. 164).

Progressive education requires them to change their role from controlling authorities to guiding facilitators. Most teachers have been educated themselves in traditional education environments. Hence they cannot rely on personal experiences (Fernandez und Ritchie, 1992; Hackl, 2002). Support for teaching using the Dalton-Plan is required. From a chaos theory and complex adaptive systems theory point of view, the following points are addressed by our work on supporting teachers using the Dalton-Plan.

We have implemented a web-based platform for sharing, and discussing assignments to support learning of a group of active agents (here teachers). E-learning environments are a means to effectively support principles established by constructivist didactics and progressive education (Auinger, 2005; Eichelberger et al., 2008). It supports teachers in understanding the implementation of a Dalton-Plan enabled learning environment. This environment addresses teachers, supporting the evolution and gradual improvement of assignments.

Drawing on principles of the Dalton-Plan, teachers are introduced (online) through a set of assignments which explain the use of assignments. These meta-assignments provide an overview of how to use assignments and graphs and also provide help for writing individual parts of assignments.

For supporting active teachers working on assignments, the web-based system provides the possibility to mark assignments as examples, and tag these with respect to didactic and content aspects. The implemented system, allows teachers, who are writing assignments, to search a repository of assignments.

Figure 5 shows in the upper area a rich text editor for filling out the individual parts. The icon with the “?” on the right hand side of the edited part, links to the above mentioned meta-assignment. The area on the bottom of the screen-shot shows the area where teachers may search for examples using these tags. The assignments show in the search area show not only the content of assignments, but also which learners are actually or have been working on the assignments and show a 5-star based quality feedback. Learners may provide feedback on the perceived quality of the assignment on a scale of 1-5, and the average sum of this quality is show in the search area. The search also returns the author of the assignment, which allows to contact the author for details.
The learning environment also integrates the graph method. For each documented work section of an assignment, learners may upload files or provide text or internet links showing their work. As e-learning provides the possibility of asynchronous communication, the graph method is translated in a way to allow learners to mark how good they think the quality of their work is, where later teachers may provide their feedback on the perceived quality. This is shown in the next figure where a graph with two blue lines shows the learner's assessment of his/her work and the teachers perception of the work. The interpretation of the semantics of the emoticons is intentionally left open, so the group of learners together with the teacher may discuss the meaning of the length of the graph.
Through this work, we have enlarged the system that learns from a single course to all courses (including teachers) on the platform. Older assignments and high rated assignments from other teachers may be searched and used when writing a new assignment. This enables also teachers to actively engage in discussions and improve their work. The evolution and adoption of the learning system becomes more dynamic, through the use of the web-based environment.

4 Conclusions

Von Bertalanffy's General System Theory (GST; von Bertalanffy, 1969) aims at bridging the gap between different fields of science through abstraction. The work in this paper links learning to Chaos-theory and Complex Adaptive Systems Theory as more specific approaches to GST (Warren, 1998). First properties of chaos theory and complex adaptive systems theory are identified, then these properties are linked to learning in general.

The Dalton-Plan is described as a particular didactic approach, which allows to implement the discussed properties of chaos theory and complex adaptive systems theory. A web-based learning environment is briefly described, which expands the learning support to include teachers. This web-based e-learning environment also provides functionality for learners to prepare their own assignments and to evaluate results of other learners. This allows make use of the e-learning environment in approaches like the Freinet pedagogy, where learners set their own learning-goals (Eichelberger et al. 2008).

The learning environment (web-tool and method) may be used in organizations and in formal training. It supports the education of self-organized active learners, who are able to work in thrivable organization. Additionally the approach taken in the design of the web-tool facilitates building of a community of practice (Wenger & Snyder, 2000) for teachers in order to share, discuss and improve assignments. As such the web-based system supports self-organized, active teachers in creating a chaotic, complex and adaptive learning system.
The presented method and web-based tool supports teachers and students in building a thrivable organization, and supports teaching thrivability through the developed instruments.

References


About the Author

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Georg Weichhart has worked as software architect and project manager at private companies, participating in several international research projects with focus on software agents supporting automotive supply networks. Later he joined the Department of Business Informatics – Communication Engineering (Johannes Kepler University, Linz, Austria) where the focus shifted towards learning support in organizational (supply) networks. His research focus is technology enhanced learning. Georg Weichhart is giving blended learning classes using the Dalton Plan pedagogy, supported by a web-based e-learning environment. He has published articles about technology enhanced learning, support for organizational networks as complex adaptive systems, and multi agent systems.