MassCustomization for Individualized Life-long Learning: Needs, Design and Implementation

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Abstract

We have reached Globalization 3.0; according to Tom Friedman's book "The World is Flat" globalization has become reality not only for countries and international corporations but also for individuals. How can one single individual compete with millions of other people worldwide? How can one person cope with the exponentially growing resources of knowledge? Definitively the key is learning and education; individualized, life-long, efficient and effective however.

Our proposal is to replace the paradigm of traditional education from an "economy of scarcity" with an "economy of self-generation". MassCustomization (MC), understood as roof for mass customization, customer co-creation, and open innovation provides the conceptual and operational framework for analyzing needs and the status of individualized education. Consistent with MC a system for individualized lifelong learning from kindergarden and school to university and corporate level has been designed and implemented. Consequently cases, i. e. outputs of education are used for customization and to individualize curricula. Latest findings from neuroscience and systems theory are utilized as basis of argumentation. First results are reported and discussed.

Keywords:
Knowledge, complexity, dynamics, globalization, education, brain, neuroscience, systems theory, logistics, life-long learning, efficiency and effectivity, sustainability, MassCustomization, roles, attitudes, content-context interface, push-pull strategy

1 Introduction

For more than 100 years the concept of mass production has been at the core of industrial development. Advantages and disadvantages are obvious: low production costs, high quality of products, amortization models for high development and marketing efforts but highly standardized products with low potential for individualization.

Interestingly enough the first concepts of mass customization (MC), aiming at balancing benefits from mass production and individualization, appeared in 1899 in France in a picture by Jean Marc Cote, see Fig. 1.

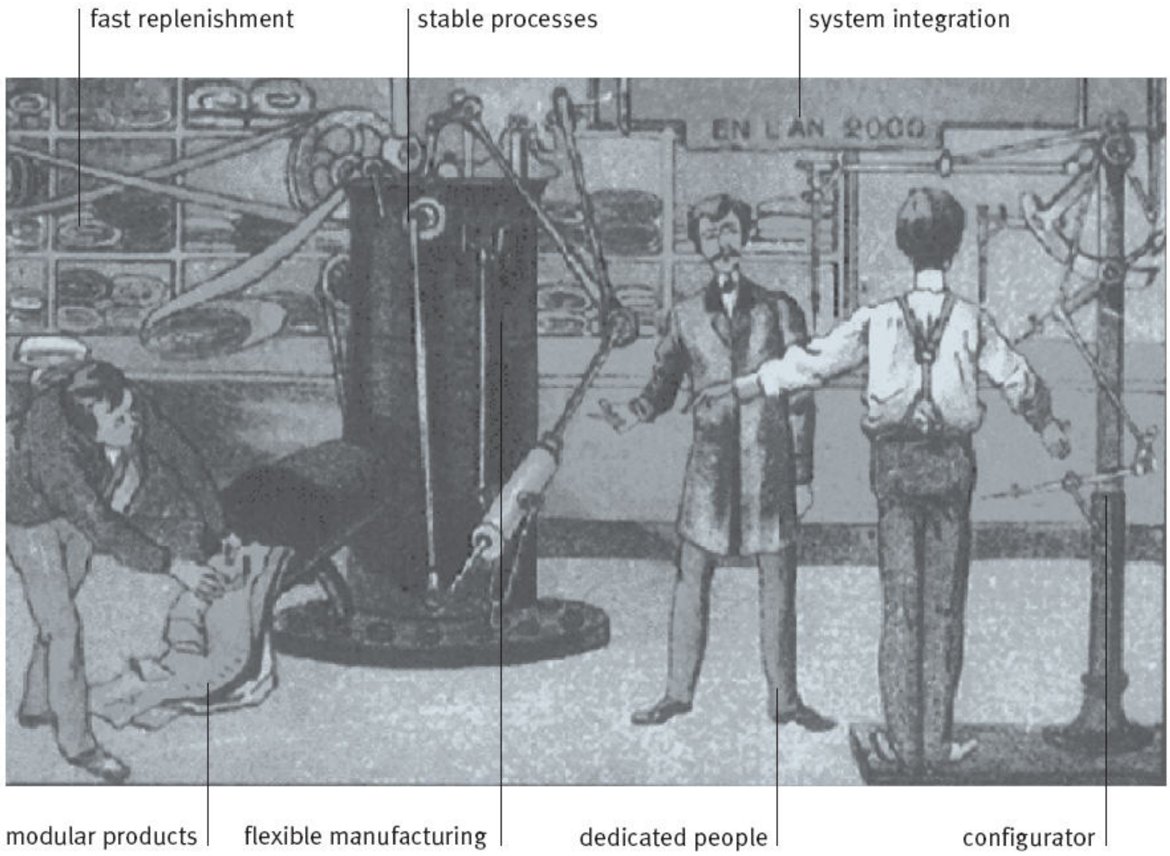

Fig. 1: Mass Customization as seen in 1899 in France by Jean Marc Cote

Piller (Piller 2006) defines mass customization as:

> Mass customization refers to a customer co-design process of products and services which meet the needs of each individual customer with regard to certain product features. All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes. As a result, the costs associated with customization allow for a price level that does not imply a switch to an upper market segment.

However MC did not reach the masses until effortless and cheap communication and collaboration tools became available. Interestingly it was not enough however to have "just e-mail" as in the mid 90's. The key to success was sharing individual experiences, pictures, media, ideas and emotions within a broad community. Headlines for this new quality of internet are WEB 2.0 and social computing. Websites like flickr.com, youTube.com, and del.icio.us are representatives for this new type of service.
Social computing opened the doors for innovative partnerships between customers and suppliers. More or less MassCustomization, Mass Personalization, Open Innovation merged into one field, we call it MC. Supported with configuration tools provided by the supplier, customers

are configuring and customizing products to meet their needs. Co-creatively supplier and customer are developing and/or enhancing individualized products and services within a framework called solution space. Product specifications like drawings and parts lists are directly transferred into the production process without further costs for marketing and sales. Typical “MC products” are individualized snowboards, wrist watches, shoes, sport goods, customized bicycles, clothes, or T-shirts.

Today the concept of MC finds growing acceptance not only in B2C markets but also in B2B markets. Examples from Festo www.Festo.com , supplier for industrial automation components, systems and services, are the so called “valve terminals”.

Fig. 2: A Festo Valve Terminal: MassCustomization in B2B markets

Valve terminals are technical systems consisting of pneumatic and electronic components with some 100.000 options of combination and a broad range of length from some centimeters to some meters. The customer configures his specific solution with an electronic configuration tool provided by Festo and transfers the data online to Festo. The standardized assembly processes allows for a delivery time of only 48 hours. This includes complete testing of all components and all functions of the system. The chance to produce a specific system once more is close to zero. Speaking with Chris Anderson’s “The Long Tail” (Anderson 2006) the tail in B2B is sometimes long - very long. Further interesting concepts for other B2B branches, e.g. the plastic industry, can be found in a series of articles on strategic innovations (The premier journal for the European plastics industry 2008).

2 Needs for future education

As globalization has reached the individual the connectivity between education and work has become both an individual and a global issue: Closely linked with reduced costs and risks of transportation, communication and exchange of knowledge, Tom Friedman (Friedman 2005) in his bestseller "The world is flat" identifies three areas of globalisation over time:

- Globalization 1.0, driven by countries,
- Globalization 2.0, driven by multinational companies,
- Globalization 3.0, driven by individuals, collaboration and competition globally.

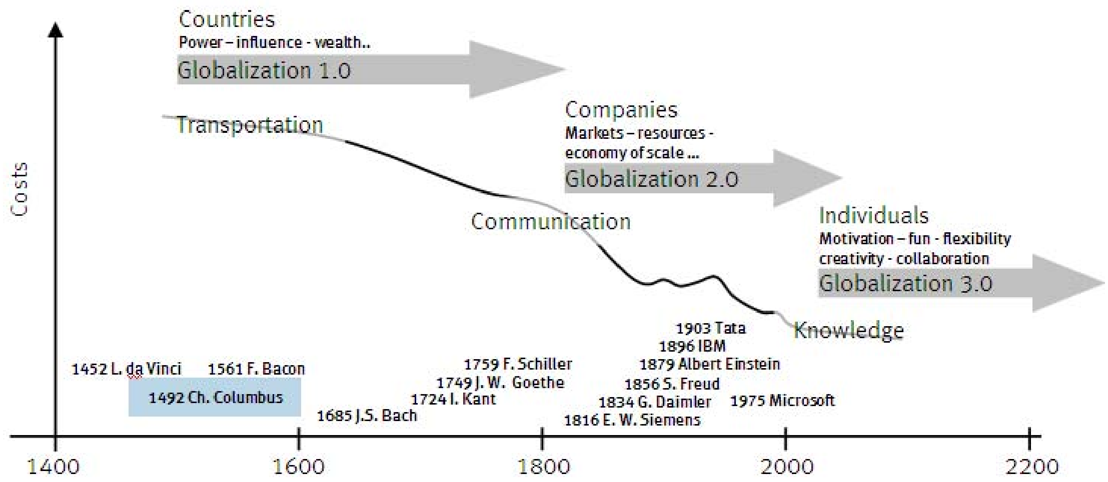

Fig 3: Changes in globalization

Therefore in the ongoing discussion on education in Germany OECD Pisa coordinator Andreas Schleicher recommends to raise the quotes for students to go to university from some 30% in Germany to 95% over the next 5 to 10 years like in Finland (Schleicher 2008). Nobody knows however which education will be needed then. Therefore education for individualized lifelong learning must at least in parts become configurable by the learner. To keep track the new process needs to ensure connectivity or even better to be a bidirectional interface between education and work.
Reflecting these changes the aim of "personalising learning" is of growing prominence in scientific and policy discussions on education's future. So it is a natural component of OECD's CERI programme on 'Schooling for Tomorrow' (OECD 2006). "Personalising education springs from the awareness that "one-size-fits-all" approaches to school knowledge and organisation are ill-adapted both to individuals' needs and to the knowledge society at large. .... But "personalisation" can mean many things and raises profound questions about the purposes and possibilities for education."
In the report's chapter on "The future of Public Services: Personalized Learning" Charles Leadbeater (Leadbeater 2006) covers mass-customization and mass-personalization. He concludes: "A mass, personalised learning service would be revolutionary. By giving learners a growing voice, their aspirations and ambitions would become central to the way services were organised. At the moment the heart of the system are its institutions and professions – teachers and schools – that lay

down what education is and how it should proceed. Studies of performance management across a wide range of organisational fields show that productivity invariably rises when people have a role in setting and thus owning their targets. The same is true for learning.
This implies far-reaching changes in the role of professionals and schools. Schools would become solution-assemblers, helping children get access to the mix and range of learning resources they need, both virtual and face-to-face. Schools would have to form networks and federations which share resources and centres of excellence. An individual school in the network would become a gateway to these shared resources…"

Faced with the diversity-efficiency dilemma, private companies apply 'mass customization' strategies to add diversity without adding costs. As schools are urged to become more personalized and customer oriented they also face a diversity-efficiency dilemma. Sietske Waslander Rijksuniversiteit Groningen in her report on "Mass customization in schools: strategies Dutch secondary schools pursue to cope with the diversity-efficiency dilemma" (Waslander 2007) asks how Dutch secondary schools cope with this dilemma and to what extend they apply 'mass customization' strategies. "A careful selection procedure aimed at maximum variety of school practices, resulted in seventeen schools for which case studies were conducted. Data collection included written material, observations and interviews. Analysis of the combined data indicated six dimensions along which schools differentiate their educational offerings:
The first dimension refers to the *goals*, ranging from school practices where the same goals apply to all students within a given track, to practices where different goals apply for ever single student.
A second dimension refers to *content*, ranging from schools where all students take exactly the same courses, to schools where students are free to choose what they want to learn, irrespective of the track or programme they follow.
The third dimension has to do with *pace of learning*, ranging from schools where all students need to complete tasks within a given timeframe, to schools where students can work entirely in their own pace, irrespective of their age or year group.
The use of *learning materials* is the fourth dimension, ranging from schools where all students work with the same material, to schools where different materials are used for different students, for example a book for student A and a computer for student B, or one textbook for student C and another for student D.
The fifth dimension of diversification refers to *learning activities*. In some schools all students are engaged in the same learning activities, whereas in other schools different students are involved in different activities. In this last case some students may work alone, while others work together in small groups, while still others attend lectures in large groups.
The last dimension refers to *timetables*, discerning tightly ordered school days from regimes that allow students great freedom to choose when they want to start, finish or have a break.

Based on emerging patterns of differentiation, four categories of schools were distinguished:
At the lowest end of this continuum they find the *Guards*, offering hardly any diversity. At the other extreme they find the *Radical Customizers*, offering by far the most diversity. In the middle they find two categories of schools that not so much differ in the amount of diversity they offer as well as in the way they do. *Differentiators* capitalize on differentiation of content and pace, while *Economizers* try to offer differentiation by means of diversifying learning materials and learning activities.
These categories appear to be closely linked to organizational strategies pursued by schools:
The main strategy adopted by Guards is to *reduce heterogeneity* of the student body. By all appearances, this strategy may require a school to have considerable control over its intake, be it overt or covert. If reputation and market position are indeed conditions for pursuing a strategy of reducing heterogeneity, this strategy will only be a viable option for a selected number of schools.
Radical Customizers try to escape the diversity-efficiency dilemma by *adding resources.* The two Radical Customizers in this study offer their students fully customized education. Both schools are deliberately small and both operate within the margins of the educational system. In a sense, these schools reflect the severity of the diversity-efficiency dilemma. Even small schools need substantial additional resources in order to customize education, making it highly unlikely that their strategies and practices could be adopted by larger schools.
Few schools will thus be able to meet the necessary conditions to escape from the diversity-efficiency dilemma, leaving many schools to face the dilemma in its most severe form.

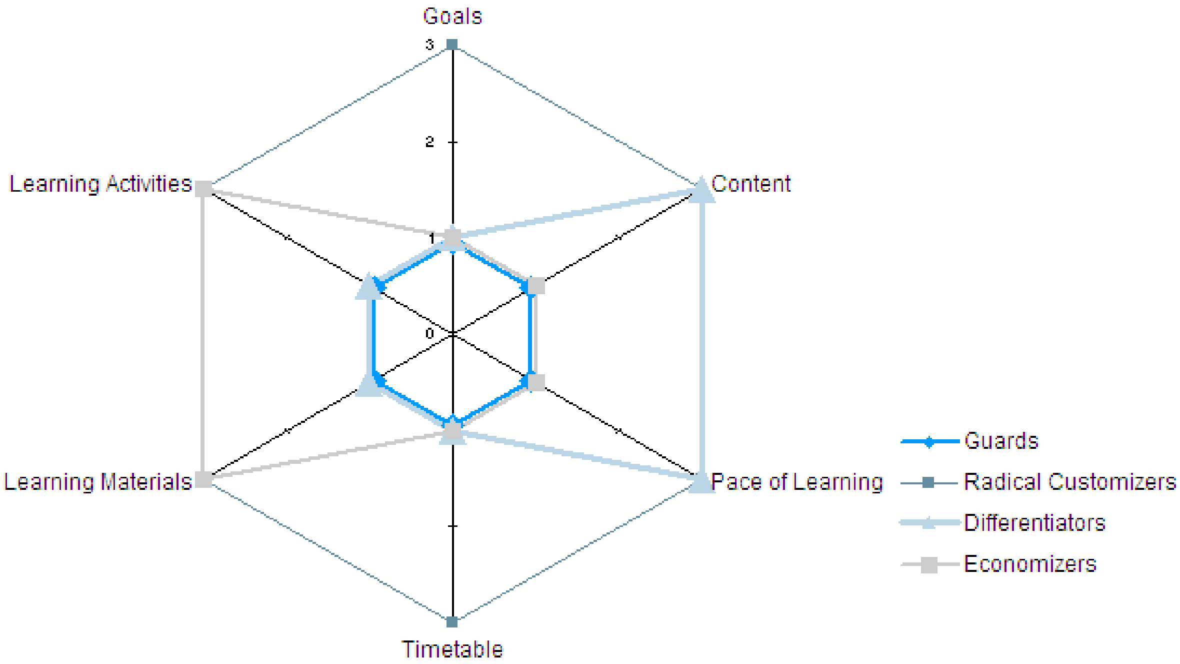

Fig. 4: Patterns of diversification in Dutch schools

Differentiators attempt to *postpone the decoupling point* and a strategy following almost naturally from it: *collaborations and combinations.* Schools applying these strategies decompose the curriculum into standardized modules, leaving it mainly up to students to build their own learning pathways by mixing and matching modules. While modules themselves are nothing new in education, the modularization that these schools have employed crosses the usual organizational boundaries between tracks and year groups, and that is certainly new. By modularizing all courses in all tracks for all year groups, schools seek to maximize the number of possible combinations that are available to students. Some schools go one step further and collaborate with institutions that are further along in the education chain. Hall and Thomas (Hall 2004) have reported similar developments for the UK. If any conditions are vital for this set of strategies, school size and the number of tracks offered are the likely candidates.
Economizers, finally, apply the strategy to *enlarge the unit of organization*. This educational version of exploiting economies of scale follows a basic economic principle to achieve efficiency gains. The three schools adopting this strategy most rigorously share important contextual factors, indicating that both economies of scale and economies of scope are relevant issues. These schools were part of a large school board with a correspondingly large budget, making appropriate new housing possible. These boards also utilize economies of scope. The boards act as regional monopolies, aiming to diversify their services in an attempt to cater to all educational tastes. Loss of clients is hardly a threat for these boards: students not attending one school are most likely to attend another school of the same board. At a general

level, the two other schools in this category share these characteristics. These schools are also secluded from local competition between schools and received additional funding to enable new buildings. It might be that protection from competition and access to appropriate accommodation is necessary conditions to adopt this strategy. If this turns out to be the case, few schools will be able to meet these conditions at short notice.
All in all, many – if not most - schools will turn into Differentiators, since the strategy of modularization requires the least strict conditions and is therefore a viable option in many situations. "
The paper concludes that practices adopted by schools to cope with the diversity-efficiency dilemma strongly resemble mass customization strategies applied by companies producing tangible goods.

3 Design elements for a system of individualized lifelong learning

In search of new ways to deal with increasing complexity and dynamics in education focusing on the core process of value creation appears to be a very promising approach. There are 4 fields of innovation to be looked at and to be synergetically integrated:

- Neuroscience
- Systems theory
- Logistics
- Collaboration and communication.

Neuroscience

Neuroscience clearly indicates that efficient and sustainable learning is a highly individual process, depending on the individual's background, the lessons learned, interests, emotions, attitudes, motivation and more. However there is a frame work of communalities we humans share in our brain functions. It is the interconnected functional structure consisting of the 4 function blocks for perception, memory, evaluation and activation.
As we all know it is not very efficient for example just to try memorizing something. The first hurdle already is to overcome the "evaluation barrier" and to reach the memory at all. The evaluation function of the brain decided mostly unconscious whether a signal from the outside world, it may be pictures, noises, speech, words … is relevant or not.
If not, the signal is not accepted for further processing.
There are no dedicated spaces for each function in the brain. Each neuron is linked with about 10.000 other neurons; they inhibit or fire, influenced by each other. They are forming ensembles of neurons in a most flexible and dynamic way.

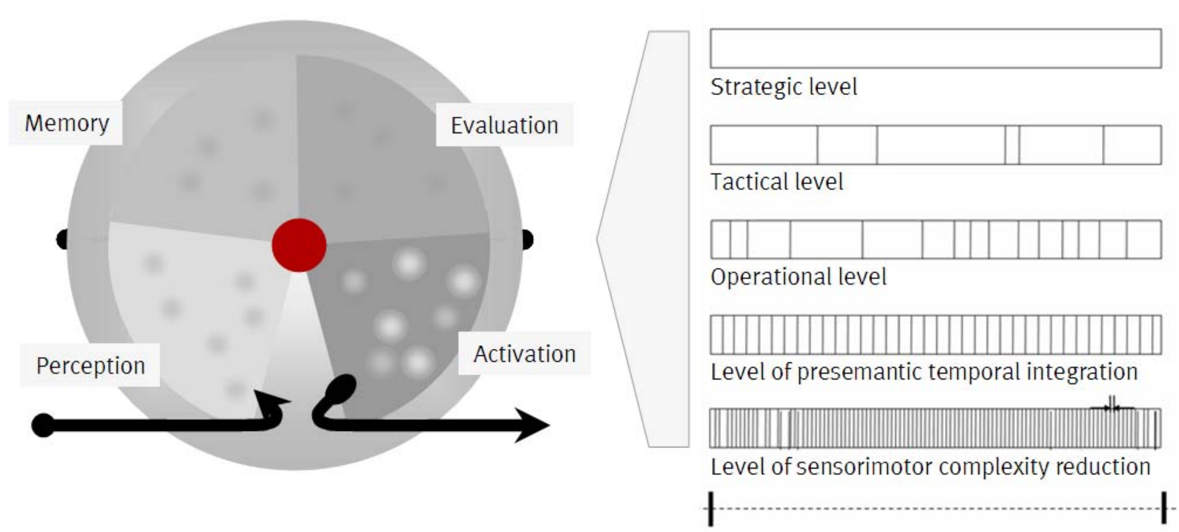

Fig. 5: The functional and hierarchical time structure of the brain

Timing is a very important strategy to structure and coordinate processes (Pöppel 2007). Time windows in the brain can be observed from outside looking into the electromagnetic spectrum transmitted continuously from the brain. Induced emission of radiation or changes in the blood chemistry show other time windows.
The shortest time window see fig. 4 is a window of 30 milliseconds duration. As signals from different sensors like ear or eye have different pre-processing times, 30 ms is the time window the brain assumes that all signals in that time window belong to the same event and are simultaneous.
The next longer time window is about 2 to 3 seconds long. This is the temporal platform for conscious activities. As the hierarchical model in fig. 4 shows there are time windows of longer duration as well. As Pöppel points out, the automatic temporal integration of successive events is provided on the next higher level. To make this happen there must be an anticipatory control mechanism on that higher level. The underlying mechanism is well known as a generalized reafference principle (Holst 1950). An essential feature of Pöppel´s model is "that optimal learning must be embedded in a structure allowing goal orientation or anticipation of what could and should be attained by learning. Without the definition of a goal, the knowledge seeker would be treated as a passive learner neglecting the possibilities of intrinsic motivation provided by the goal, which is the driving force of successful learning an the creation of knowledge. Thus, a learning episode is embedded in time...Time required to reach this goal can sometimes be years, although it takes just seconds or even milliseconds."
From neuroscientific findings we know, that the human brain is organized for effortless learning. The mechanisms to set learning goals, to define successive steps, to evaluate and to correct outcomes are essential parts of human learning.

Systems Theory

Heinz von Förster (Förster 1988) calls systems which show deterministic input-output relations trivial machines. Non-trivial machines are systems showing internal stati, depending for example on their learning history. As opposed to trivial machines non-trivial machines do not show the same output for the same input.

Trivial Machines	Non-trivial Machines
Synthetically determined Analytically determinable Independent from history Predictable behavior	Synthetically determined Analytically un-determinable Depending from history Un-predictable behavior

In this sense the human brain is clearly a type of non-trivial machine and it should be treated as such.

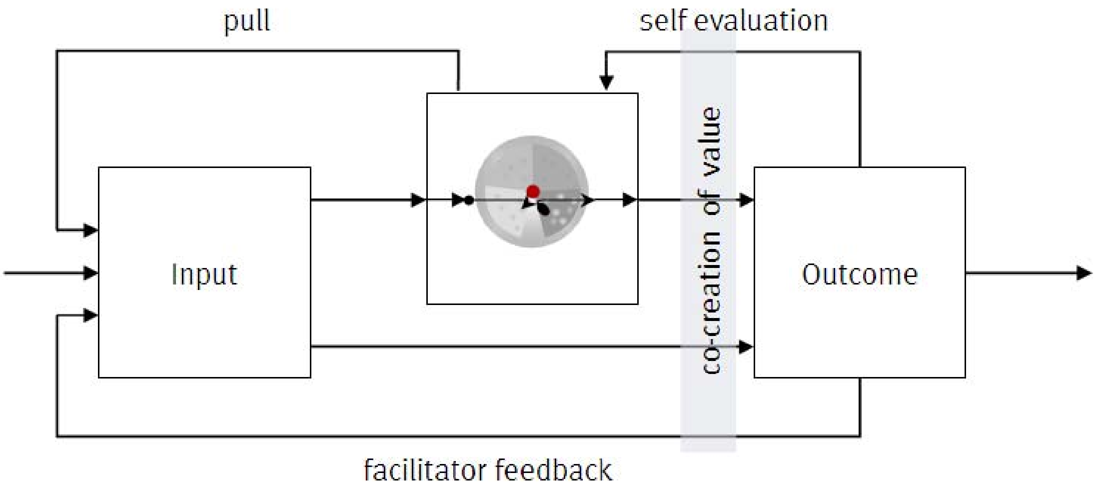

Fig. 6: The human brain modelled as non-trivial machine

We take the human brain as the "black box" in the center of fig. 6 and add input and outcome. In an educational scenario inputs are all providers of education, the organization, individuals or the media used. As we take the brain as an undeterminable system the outcome from the brain will only be determined by the brain itself. The outcome can only be worked on directly through the input itself getting feedback from the facilitator feedback loop. The learner's feedback loop is set through "self evaluation". Through the "pull line" the learner asks for delivery of appropriate knowledge from the educational source; an obvious argument for a guided selforganization of successful learning scenarios.

Logistics

Experiences from complex material logistics e.g. in car production (Womack 1990) clearly indicate that high complexity in delivery of components “just in time” can only be handled with a “pull type” of control.
As opposed to “push type” control “pull type” means, station “n” in a delivery line asks for delivery from station “n-1” just in time and on demand. “Push type” control implies that the flow of material is planned from the past into the future as carefully as possible and the material flow actually will follow. Due to the likelihood of unforeseeable events however this type of regime only works as efficient as anticipated if conditions are stable enough over time.

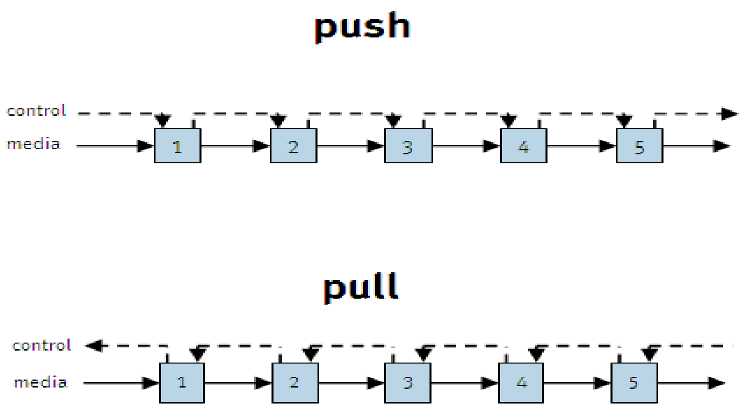

Fig.7: Push and pull control structures

Obviously the past has shown that human learning is never stable neither for individuals nor for groups.

Communities and Collaboration

Social computing, WEB 2.0, open innovation, crowdsourcing are neologisms based on “cooperation and resonance” as an innate behavior of human beings (Bauer 2007). Best practices like Wikipedia, Linux, numerous blogs are known and used world wide. To build sustainable communities all individuals much share common visions and goals, trust on co-creation of value, owe the attitude to share and be motivated to achieve.

To handle the diversity-efficiency dilemma for individualized education we suggest adapting the MC definitions worked out by Piller (Piller 2006) to the area of education and further differentiate it using the 4 fields of innovation mentioned above.

> Mass Customization for education MC4Ed refers to a learner co-design process of educational products and services which meet the need of each individual learner with regard to the 3 dimensional solution space set up by the dimensions of learning content, learning context, and time and place to learn. Within the solution space offered, see fig. 8, learners are empowered by the providers of education to find their best solutions, configure it the best way

possible, and get it “delivered on demand” and “just in time”. The pull type learning process is seen as a co-creative and cooperative process of providers of education and learners. It comprises both the initial configuration phase as well as the co-creation of the individual solution as a continuous improvement process for education.

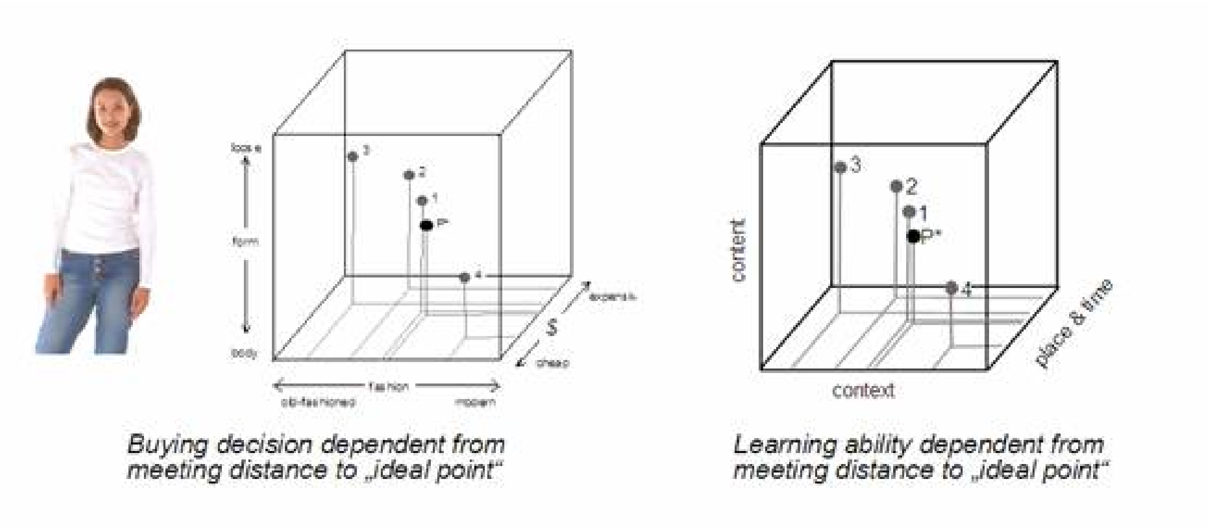

Fig. 8: Solutions space for clothes as compared to education

4 A learning system for individualized lifelong learning iL3

The following practice report is intended to shed some light on possibilities of applying MC strategies and experiences to an educational framework.

The pilot project for individualized lifelong learning iL3 at Festo is set to cover 5 dimensions:

- Age from 5 to 50 plus
- Education from kindergarden to school to university
- Bridging scenarios of formal education and informal/non-formal education
- Contents cover technology, sciences, management
- Context in leisure time, vocational education, professional areas

Following the MC4ED strategy developed in the previous sections all iL3 activities are based on the same structural building blocks, processes and tools. Up to date information on iL3 can be found on www.applied-knowing.org.

Program:
It consists of a varying number of modules to cover a curriculum or parts of it. Realized examples and in preparation are programs for vocational education, in company trainings, university level programs (Fig 9 and 10)

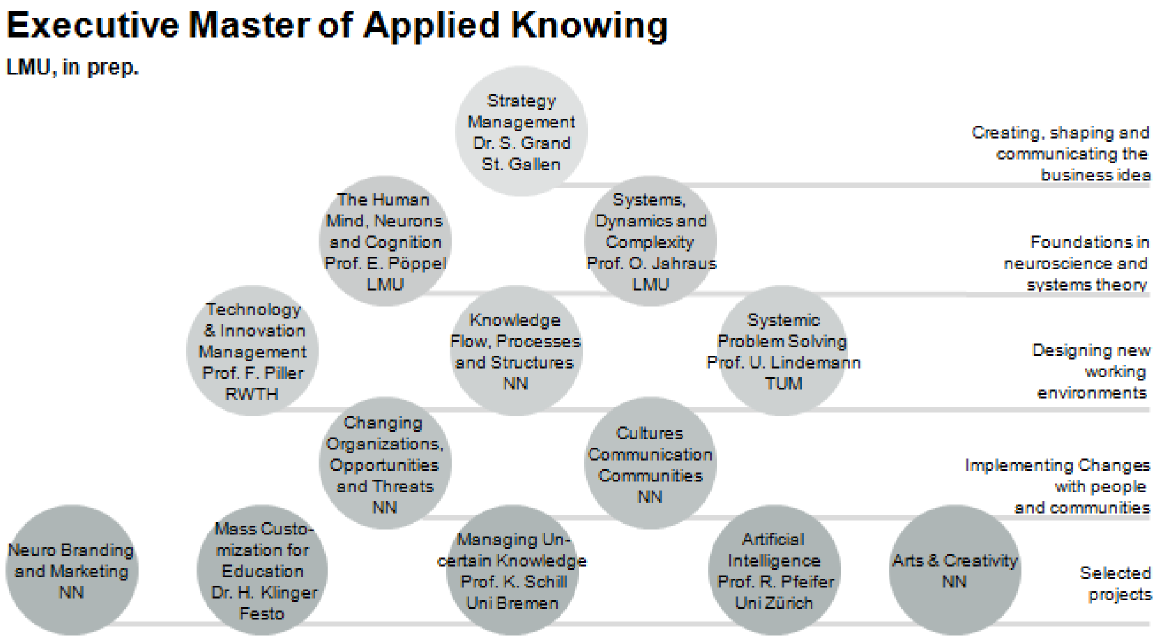

Fig. 9: University Master of Science “Applied Knowing”

Both programs are university level master programs with 9 mandatory modules. Duration per module is 8 weeks on the job. Sequence of modules is configurable by the learner. Minimum time for the complete Masters Program including master thesis is 2 years.

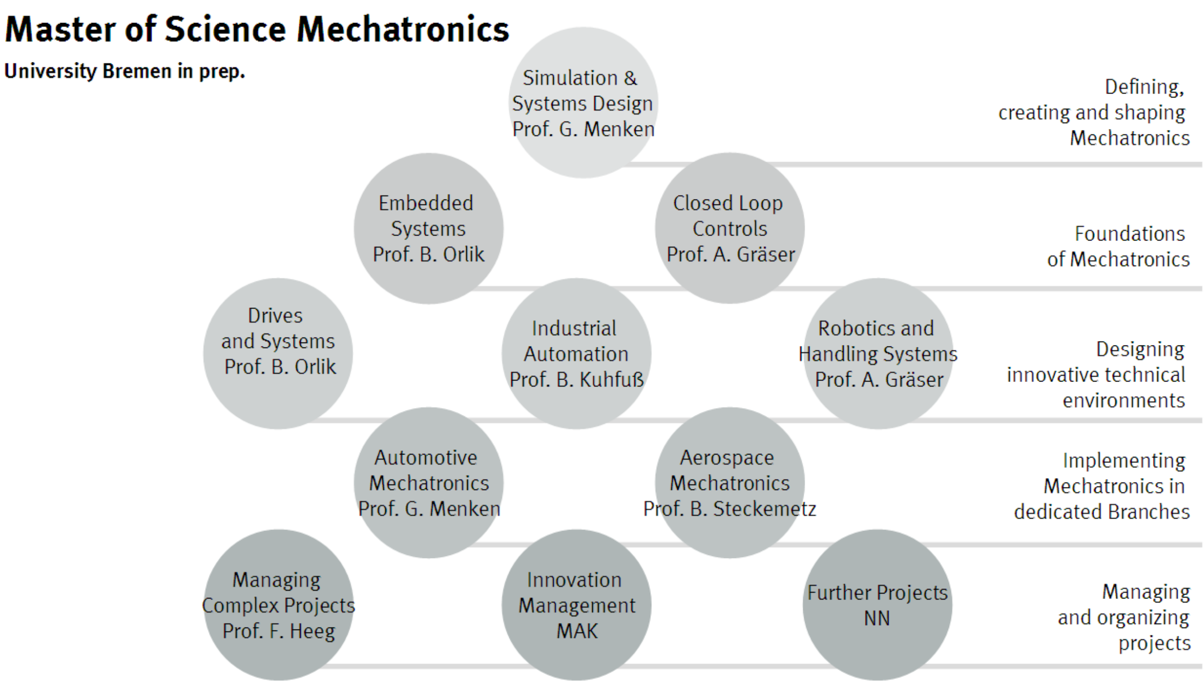

Fig 10: Master of Science Mechatronics

Module:
Defined learning contents covered by cases to be solved in a project type style with 4 defined phases, see Fig 11.

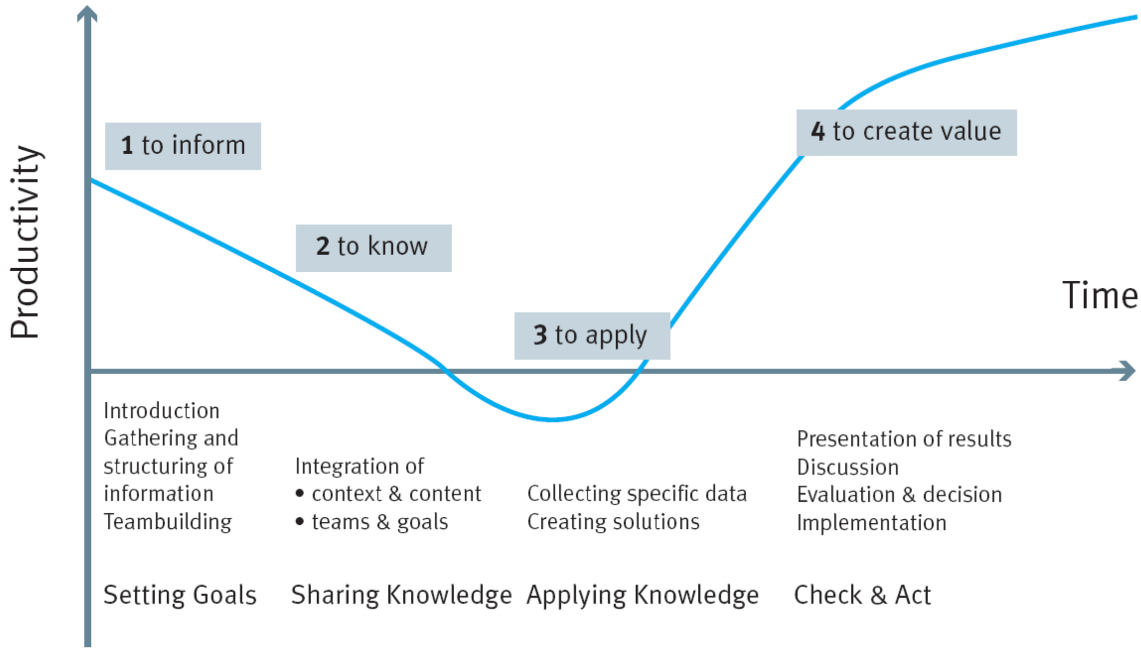

Fig. 11: Standardized learning process for iL3 modules

Cases:
Cases are co-creatively developed out of case assignments strongly referring to relevant context of learners. Typical context is the working environment for in company training, the further career of students, or just individual interests. There is a standard structure for case assignments with a description of a starting point and the task to solve the case. Adaptations and fine tuning of the case assignments both through “teacher” and learner are happening regularly over the course of the module. Changes are documented and part of the reflection process in phase 4, see fig. 11.

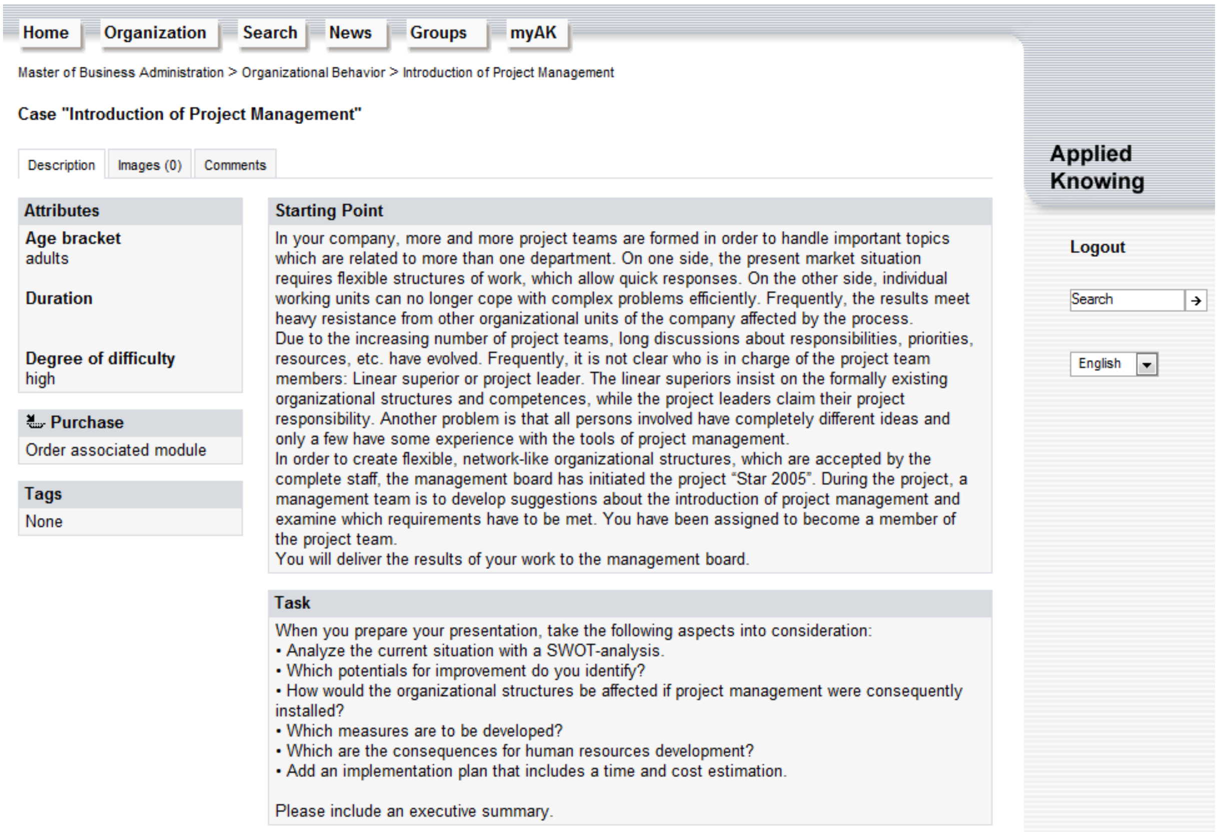

Fig. 12: Standardized structure of configurable case assignments

Roles:
Consistent with findings from neuroscience and systems theory the learner has to be the process owner of his individual learning. Teachers are facilitators e.g. to enable students to select and configure appropriate cases for a specific module, to assist teamwork as an expert or coach, to deliver knowledge contents “just in time” and “on demand”.

Configurator:
Like in traditional education the top down configuration starts with a pure selection of a program and/or the modules attached to it. On the module level however the learner can select between different case assignments. The learner co-creatively adapts the case assignment with his team of students and the facilitator.
For special interest groups we also offer bottom up configuration from selecting cases first, to bundle modules to individualized programs and link them with knowledge maps. This approach is interesting for leisure time activities e.g. fans for robotics or corporate trainings, see fig. 13.

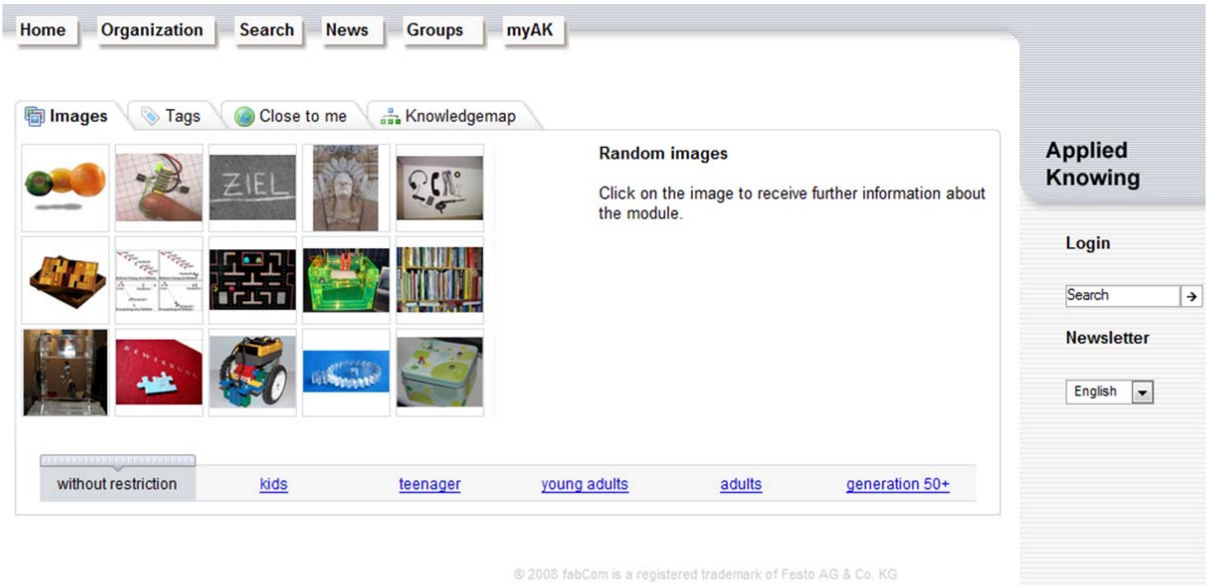

Fig 13: Age depending iL3 online configurator

Development:
As the learning process is a co-creative process of learner and teacher developing new materials and ideas for individualized lifelong learning is an ongoing process, see Fig. 14.

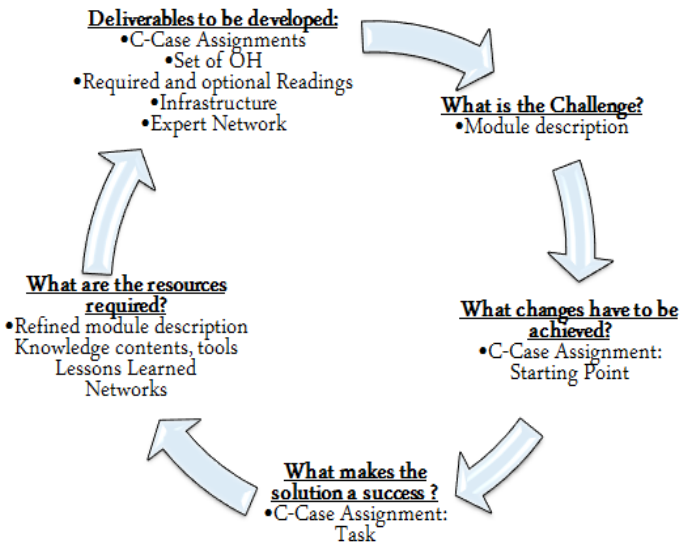

Fig 14: The co-creative and continuous development process

To enable open innovation an internet platform called case-factory was created. The case-factory is aiming at learners at al levels to share their ideas with others and document them in a standardized form as case assignments. More information at www.applied-knowing.org.

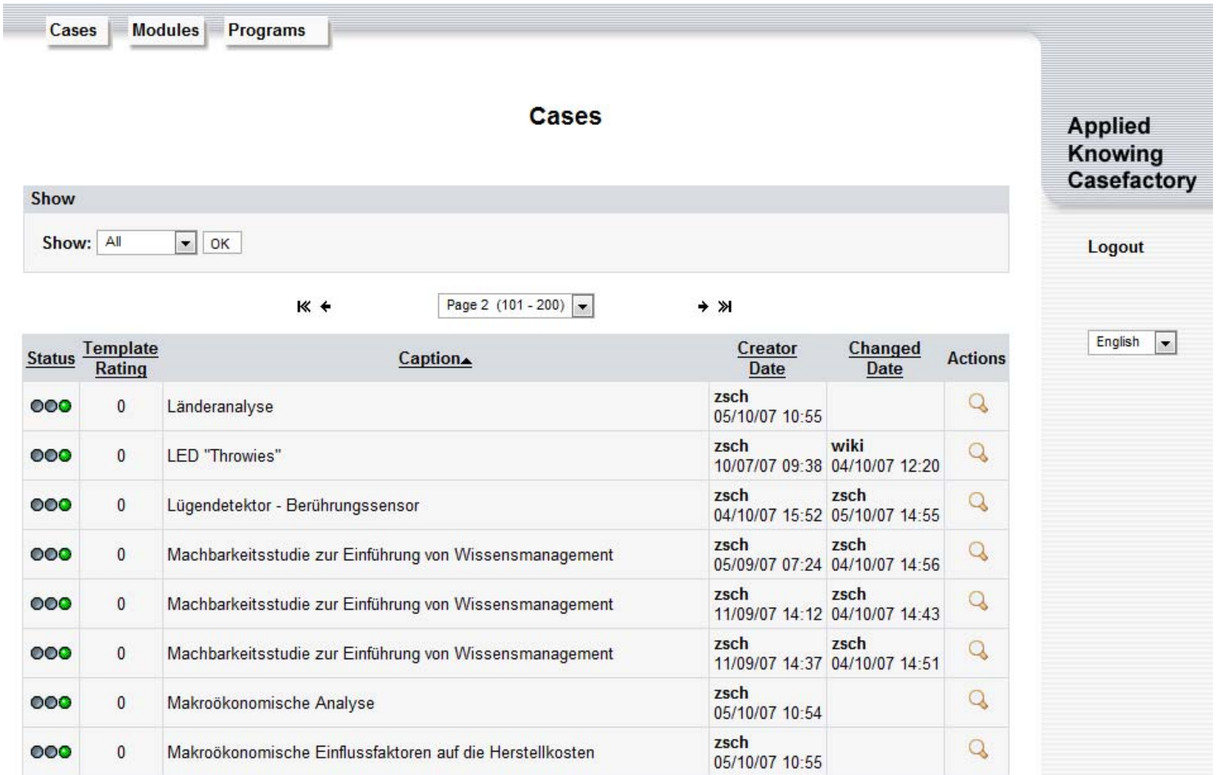

Fig. 15: The Case-factory as a platform for open-innovation in education

5 Lessons learned and recommendations

The challenge for education in the future is to solve the diversity-efficiency dilemma of individualized learning. We used MC concepts and operations to set up a pilot project for individualized lifelong learning iL3.

The feedback from learners from all ages, educational levels and subject areas is very positive:

A.K. “Preparing a solution for my own problem and at the same time learning was an unexpected and in deed authentic learning experience.”

M. L. “At first I was appalled when they told me we had to learn this topic in self organizing teams but in the end I was amazed of how much and how fast we were able to learn and at the same time apply.”

M. K. “It was amazing how much knowledge there was in the course and in my team and how much creativity the intense discussions were able to bring forward.”

S. Q. “Having the opportunity to learn self-organized at my own pace but still knowing that in case I am stuck there is someone I can talk to gives security and helped me to create a new self confidence for future tasks.”

H. K. “The applied knowing method was a great way to bring knowledge into application.”

It clearly proofs that consistent with our assumptions from neuroscience and systems theory learners are willing and able to select and configure individualized cases also in content areas new to them.

Case assignments are specifications for individualized learning goals and can be used as means for diversification. To actively define them creates motivation and structure for the learner to self-organize individual learning steps, milestones, evaluation criteria and to synchronize the individualized learning process in a highly customized way with teams.

Teams have to be as heterogeneous as the members feel it to be helpful to reach the common goals.

The role of teachers has to change from a person to push content to a person facilitating learning.

In all scenarios we looked at our approach to ask learners to configure and customize prepared case assignments provided enough diversity for the learner to accept the learning situation as personalized learning. On the other hand the standardization of the internal structure of programs, modules and cases is high enough to make iL3 work efficiently both for students and for teachers.

Sometimes students “complained” having spent much more time than anticipated but they enjoyed to do so.

According to their new role as facilitator and coach after a phase of change teachers spend more time at the core process of learning with individuals and teams. In addition to that a lot of knowledge transfer is done “just in time” and “on demand” through peer to peer communication. The average time teachers spent in iL3 was about the same as before.

To customize education we consequently used the innovative paradigm of “output orientation”. This is in direct conflict with the more mechanistic philosophy of education: pre-defined knowledge pieces have to be delivered first like pieces of a partslist to be assembled later for any application by the learner himself. Our results clearly indicate that learning and applying knowledge are two sides of the same coin.
On of the issues of a further project planned in educational systems in 5 EU countries therefore must be to change mindsets and paradigms. Of course we are using the MC approach to achieve the goals!

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