1st Workshop on Exploring the Fitness and Evolvability of Personal Learning Environments (EFEPLE'11)

At the 2nd STELLAR Alpine Rendez-Vous (ARV)

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RESPONSIVE OPEN LEARNING ENVIRONMENTS
ROLE

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1. INTRODUCTION

1.1 Motivation

In the recent decade a plethora of interactive software tools, be they open source or proprietary, have emerged and perished in the realm of technology-enhanced learning (TEL). Concomitantly, there have also been surge and demise of contents, social networks, and activities associated with the use of these TEL tools. It is intriguing to understand what factors contribute to their rises and falls, and how. While controversies on the viability of making an analogy between the evolution of natural and artificial objects prevail, it is deemed worthwhile to explore its potential for analysing the changes in TEL and charting the future.

In accordance with evolutionary theory, the fitness of an environment or tool can be defined with respect to its purpose and depends on the 'genes' from former generations. In context of TEL, these genes can be understood as features of existing tools and functionality being reused from software libraries or developed over multiple lifecycles thus leading to new generations of software artefacts. Personal learning environments (PLEs) aggregate these functionalities to enable learners to connect to peers and shared artefacts along their learning activities. Consequently, the success of a PLE can be measured by its uptake and usage within different communities of practice, its perceived effectiveness and efficiency in supporting the attainment of learning goals, its application beyond pre-defined purposes, its distribution and outreach beyond single communities, and its evolution to new PLE generations through active developers. Moreover, data mining of so-called *variables of evolvability* (e.g., perceived pragmatic/learning and hedonic/fun value) will enable the derivation of specific guidelines for designing and developing PLEs. Such empirically grounded guidelines, supplementary to those for generic IT applications, are currently lacking and much desired.

Overall, the main aim of the workshop is to explore the fitness and evolvability of PLEs in order to identify and understand characteristics and mechanisms for successfully evolving PLEs.

1.2 Related Work

In principle, for a software system to be sustainable, it needs to be able to adapt to the changing requirements [1] in terms of use contexts, user goals, organizational cultures and technological opportunities. Specifically, in the field of TEL, there has been a shift from the pioneer work on designing and implementing full-featured, organisation-driven learning management systems (LMSs) to the emerging trend of developing specialised tools, which then can be assembled by users to extend/create personal learning environments (PLEs, Attwell, 2007) [2]. Not least due to the Internet, users have access to a seemingly innumerable amount of content and software tools, which are useful and partially even necessary to achieve the learning goals driven by the demands of job tasks, higher, and further education, or even private activities.

In the context of PLEs, the selection of tools is at the discretion of individual users, their organisations and the communities of practice (CoP) where users engage in a variety of collaborative activities. It is observed that some software tools, after being used for a few typical tasks by a few people only, unexpectedly spread out within a CoP widely as well as wildly through good practice sharing, convincing peers of the benefits of these tools for particular lifelong learning activities. In a very short period of time such tools can become as must-have infrastructure for collaborative work (e.g. various Google services). These tools and the environments built on them are not only intensively used but are also modified and sustained by active developer communities. On the other hand, some tools are endangered to be rejected by end-users and to die out after a few successful cases of application, even though they have undergone several iterations of redesign. Apparently, these observations manifest the notions of *descent with modification, heritable variation and selection, sensitivity to changing environmental or contextual requirements, and "control of and types of variability"* (Nehaniv, 2003 [3]; Wernick et al. 2004 [4]) that characterize Darwinian evolution. In the context of PLEs, it is relevant to understand the processes leading to successful tool uses, create respective models and learn how to control respective processes to increase the efficiency and effectiveness of modern individual learning environments.

The assumption that changes in PLEs can be modelled by Darwinism underpins this proposed workshop, which aims to explore several pertinent issues:

- Nahaniv et al [5] (2006) define the notion of *evolvability* as *"the capacity to vary robustly and adaptively over time or generations in digital and natural systems"*. This definition leads to a basic question: **What is evolvable**? Is it a matter of the complexity of a system that is quantifiable such as lines of codes, number of modules? Or is it more a matter of quality-in-use manifests in terms of user experience [6] (i.e. a non-functional requirement)? Another key question: **Why does a system evolve?** It can be instigated by changes in a system's environment, user requirements, usage, implementation methodologies and technologies. Answers to these *what* and *why* questions can shed some light onto the question **How to effectively and reliably evolve a system** (Ciraci & van den Broek, 2006; footnote 3)? Addressing these questions in the context of PLEs will instigate stimulating discussions.
- Fitness for survival is a widely known but poorly understood concept of Darwinian evolution. Paradoxically, the idea of heritable variation and selection is necessary but not sufficient to explain inherent phenotypic expression of fitness (Nehaniv et al. 2006; footnote 5). It hinges on the rigidity (or flexibility) of the genotype-phenotype mappings. The main difficulties lie in drawing analogies between biological concepts and artificial artifacts (e.g. What constitutes an "individual", a "species", or "interbreeding"). Insights can be gained from the

notion of *fit-for-purpose* in the field of HCI (e.g. Wong et al., 2005) [7] and the fitness model of nodes in the science of (social) networks (Barabasi, 2002) [8]. Nonetheless, it remains an open question on how to define and measure the fitness of PLE tools

2. WORKSHOP DESCRIPTION

There were 10 presentations, including a keynote speech. In addition, plenary discussions on specific topics were held. Section 2.1 reports the main ideas addressed by individual presentations. Section 2.2 highlights the ideas explored by the workshop participants.

2.1 Report on Presentations

In this section, we highlight the ideas discussed in each of the presentations and present them in the form of notes that may inspire further thoughts along the related inquiries. These notes can serve as pointers to the tenets of the respective workshop papers.

2.1.1 Keynote by Prof. Chrystopher Nehaniv

- Core concepts addressed: individual, reproduction, population, robustness, variability, phenotypic plasticity, autopoiesis, self-replication and repair, and evolvability
- The notion 'replicating individual' is difficult to define in the realm of software evolution – Is it a behaviour, an artifact or software release?
- Self-replication is a key notion in evolution (cf. computer viruses, cancer cells, self-reproducing automata); replicators entail external support;
- Constraints of evolution: finite resources, heredity, variability, differing reproductive success, turn-over of generations;
- Increasing complexity through successive inheritable mutation; a measure of complexity in biological sciences can be number of cell types and in software can be level of embeddedness, lines of code, number of loops, etc.Adaptive changes in population over generations (genotype-phenotype map)
- Artificial selection vs. natural selection;
- Variability: neutral mutation (no harm, no benefit) is important: similar fitness in the same environment; mutation that is neutral in such an environment is beneficial as a resource;
- Neutral mutation such as user interfaces – a variety of choice for selection;
- Fitness landscape: inheritable fitness to flourish
- Open-ended evolution is unbounded increase of complexity over time;
- External fitness function imposed on agriculture (can we learn from this domain?); number of offspring and living long enough to reproduce (fitness measures);
- Symbiogenesis: dynamic user-synthesis of PLE from components; combinations from the lower level units;
- Evolvability for artefacts: capacity for producers to rise to adaptive variants for flexibly meeting changing requirements; lineage, different fitness between offspring and parents
- Properties of evolvable systems: robustness to genetic variability, phenotypic robustness, redundancy, conservation of core mechanisms/features; robustness to environment change (resilience), self-monitoring, compartmentalization (modularity), symbiogenesis
- Software evolution: re-use, modularity, information hiding, encapsulation, OO inheritance, coupling and cohesion;
- PLE: system as fielded (instance: individual)
- Persist over time, descent with modification
- Lines of code, modules can be considered as genes (re-usable)
- Variation: customization of generic software product via parameterization, copying and sharing
- Iteratively adapted by users to context and changing requirements;
- Immediate fitness is very different from capacity to support possible evolvability;
- Variational capacity (vary/be varied robustly and adaptively) is crucial to evolvability

2.1.2 Discussion on the Keynote

Notion of energy/resources in the context of software;

- Areas of tension:
    - immediate fitness vs. variability
    - simplicity: usability vs. complexity
    - genotype (design: functionality) vs. phenotype (affordances: practices)
- Complexity: base is interaction, energy comes from interaction, non predictable
- Consciousness/Intentionality (or awareness): comes from interaction, collaboration
- Is evolvability kind of higher level creativity
- Success: performance improvement of learners; "form follows failures"
- Complexity: maximise contact with environment subject to being able to understand and manipulate: complexity needs to be close to contact
- Educational technology so far has failed: because there are no solutions of scale (past: LMS have been successful, but not 'real' learning support tools)
- Capacity for variability: Learning is development of potential for action: competence, but we can only assess performance
- Capacity relates to complexity through adaptation through exchange of modules and over time!
- Freedom of adaptation vs. ethical concerns experimenting with bad combinations of software
- Sharing of successful practices/arrangements/etc. is hereditary replicability
- Problem: It's not the PLEs surviving and being fit, it's the widgets
- Problem: PLE: Livespan of generations is not controlled

- But: Behaviour vs. artefacts: patterns of practices vs. widgets
- Behaviour: duplication and divergence; behaviour patterns can be very far away from genetics; active copying vs. environment driven auto discovery
- Controlling of behaviour: we can (to a part) control the environment to recreate 'situations'
- Translation of behaviour (phenotype) into genotype? No convergence in other areas.
- Would be helpful to very clearly define concepts such as genotype, phenotype in the PLE context
- Groundbreaking works in e.g. evolutionary algorithms: e.g. von Neumann: theory about live; e.g. evolutionary algos: were designed as optimisation techniques (example: designing nozzles, aircraft wings)

2.1.3 Presentation by Benham Taraghi

- Success measurement:
  - Complexity: number of widgets in an environment
  - Change: rate of change: number of replacements, new widgets
  - Number of users
- Selection types: stabilising selection, disruptive selection, directed selection
- Selection strategies: r-strategy (short livespan, unknown environments) vs. K-strategy (long livespan, known environments)
- Mutation: slight variation of existing functionality or UI
- Recombination: combining code of different widgets to build new ones: code sex
- Tracking of use: frequency of activated widgets, frequency of interactions with widgets that can be tracked in the system
- TUG system: 1000 users, 30% active users
- Competition not between widgets, but between PLE system and competing websites
- Code complexity of the PLEs: PLE as a whole (of one user) or widgets? How did it change over time? Lines of code? Level of embeddedness? Modularisation? Interwidget communcation? Service orientation?
- Affordances (= in a certain cultural context)?
- Other factors (besides fitness): usability, usefulness (e.g. indirect via level of the learners)?
- Need to look at overall PLE system, not only at single widget; still: number of contexts, number of functions, number of other widgets it has been used with (degree centrality, betweenness, prestige): indicator of complexity
- Symbiotic relations: themingWidget: cannot exist on its own
- Coevolution of development and users

2.1.4 Presentation by Carlo Giovanella

- Evolution: strong focus on learning analytics: e.g. activity graphs, emotions, social networks, emotion in social networks
- Use **traces of user activity** to observe evolution
- Arrival of facebook changed the use of the system
- New journal: Interaction Design & Architecture

2.1.5 Presentation by Felix Moedritscher

- Environment: socio-technical system: activities, purposes, patterns, interaction, features, functionality, implementation
- Evolvability: versioning, copying/reusing, interoperability
- Fitness: usefulness & usability, user feedback, technological compliance
- Distribution approximation
- Fitness depends on the usage context (e.g. publication impact)
- Impact of papers very strongly relates on experience of the researcher (years of experience in a field). What about production of widgets? Are widgets produced by more experienced users more successful?

2.1.6 Presentation by Martin Memmel

- Sustainability
- Interoperability: using and offering APIs, following standards
- Number of application scenarios: very many application scenarios for PLEs
- Low technical and low conceptual barriers to system use
- Resources are finite: people, time, infrastructure, money
- Repurposing and re-theming/branding of systems
- Solve a specific problem, but do it in a generic way
- Support tools for setup and deployment
- Refactor
- Fitness is plasticity with respect to user requirements

2.1.7 Presentation by Sandy El Helou

- Viability:
  - flexible representation of interaction and contents
  - adopt social media paradigms (encouraging participation)
  - elastic community and CMS services
  - automate/openness: recommender systems: open corpus environments
- Use of Graaasp
- Flexible representation: not necessarily dependant on number of users

2.1.8 Presentation by Jose L. Santos

- CAM dashboard
- Activity – actions executed in widgets
- Capturing communcation data from interwidget communication
- Specialisation to styles?
- Active use of the dashboard to change behaviour?
- Evolution: Awareness > Social Behaviour > …

- How to support awareness between developer and user?
- Representation of context to make use of the activity monitoring
- Fitness: take care of environment
- Visual quality
- Trust relationship between developers and user

2.1.9 Presentation by Fridolin Wild

- Acceptance: expectancies, social influence, facilitating conditions etc.
- Longer term

2.1.10 Presentation by Christian Prause

- "Walking on water and developing software from a specification are easy if both are frozen." (Edward V. Berard)
- high costs of change lead to extinction
- evolvablity: internal quality
- software quality: ISO 9126: functionality, reliability, usability, efficiency, maintainability, portability
- developers learn software: documentation! Code!
- Fitness = external quality + quality in use = Tool in environment in its context
- Case-based tools

2.1.11 Presentation by Maryam Najafian-Razavi

- Barriers to adoption (of gleanr)
    - Lack of simplicity
    - Slow ROI: differed benefit
    - Need for training
    - Usability problems: memorability, error rate, portability
    - Success factors: clear value prop, awareness, ease of integration
    - Interesting: big and fluid sites show up earlier in google
    - Suggestions: anonymity, prepopulation, network effects
- Success factors: could be fitness factors
- Fitness leads to adoption
- Prepopulation: problematic and difficult
- Prepopulating vs. survival?
- Ecosystem: has to be created, needs a context

2.2 Report on Plenary Discussions

2.2.1 Contextual Issues

- Flexibilisation of technology support for any kind of educational process
- Culture of certification: assessment and accreditation;
- Fitness: Integration of environments: mobile, web, all
- Fitness of users: critical design skills, measure experience / styles
- Context: capture context of learners holistically, make this context description available to sound applications;
- Plasticity: Support change in pedagogical approaches

2.2.2 Teachers as Target Groups

- Find a way to prove to the teacher that relying on a specific technology will help them be more effective
- Tackle danger for teachers: environments disappear: but environments change with their needs
- How to sell technology to the teachers?
- Show that with the help of any technology, the learners in the classroom/course became 10% better: works only with criterion-referenced testing (no norm referenced testing): skills assessment: increase by 10%
- Emergence of new widgets coming from the teacher and learner community
- Living community: Increased sharing of best practices: 1 million teachers / million learner using a PLE; There are enough teachers in Europe
- Digital literacy of teachers is a problem
- Technology is seen as an amplifier
- Combine agents and human tutors to provide high quality tutoring to every child

2.2.3 Invisible PLE

- very low entry barrier
- Sharing a curriculum in 15 minutes
- No good idea: it is rather about reconfiguration, not sharing: more about the adoption than that it is fast
- Extremely complex issue
- Widgets: 1000 widgets: which one is better and how do we measure that? Through the community
- Testing: could include teacher has to be able to re-use a PLE in 15 minutes; but: it's not about time, it's about the return on investment
- Identifying the scores that someone gets based on the traces that someone leaves in the system
- Pedagogically sound user interfaces

2.2.4 Predictive Modelling

- Predictive models: Predicting performance based on traces
- Testing of predictive models in competitions: accuracy vs. satisfaction
- Learning analytics: graphical user interfaces that foster quick understanding of performance and aesthetic display, streaming feedback
- Learning analytics, traces, context capturing; Privacy-ensured, anonymised; Streaming analysis
- Open requirements elicitation: Implicit requirement modelling, helpdesk monitoring, Implementation competitions in the bartering platforms for software development

3. EMERGING RESEARCH QUESTIONS

- *Find a way to prove to the teacher that relying on a specific technology will help them be more effective*
    - The million practices & million teacher challenge: ad hoc formation of large scale learning networks: Reach a certain level of scale in variability and build capacity for variablity of practices of technology use in learning and teaching.
    - This includes: sharing of context information such as attention meta data, interoperability, practice capturing and sharing facilities such as scripts or learning designs or activity streams
    - This is not about showing that a certain template is used by a million people, but that 1 million people have differing, adapted to their needs practices in technology support
    - Ad hoc formation of large scale learning networks
- *Fitness of learning environments is **plasticity** with respect to user requirements:*
    - Variation: Adaptation or mutation: construction set widget-based PLE, coding according to changing user requirements, mash-ups
    - Speed of change:
        - Evidence that a trajectory is followed that a system has been adapted: evidence of plasticity
        - Knowledge management for teachers
        - Dissolving of communities of practices: problem solved, community dissolved
- *Invisible PLE*
    - Low entry barriers
    - Flexibility with respect to pedagogical and andragogical approaches
    - fitness of widgets: create an open market for widgets; then we can use the market mechanisms; show that there are widgets from each of the European countries; differing learning contexts (school, university, lll) and stakeholders (providers, learners, teachers, educational institutions)

4. CONCLUDING REMARKS

Evolutionary or Darwinist theories are inherently controversial; applying them to explain and predict the trajectory of the development of Personal Learning Environments (PLE) is particularly challenging. PLE is still at its infancy stage, and a consensual definition is still lacking. Amongst others, the task of defining fitness models for predicting the rise and demise of specific widgets (which are commonly seen as the building blocks of PLE) and a specific configuration of PLE per se is daunting. The workshop is seen as the first step moving in the direction, though there are still many steps to be taken to achieve this seemingly insurmountable task. The initial step is seen as successful with intriguing ideas being conceived. Future work includes organizing a series of related workshops/seminars that involve participants with diverse backgrounds. Project proposals addressing the emergent topics are seen as a promising way to explore them in depth over a relatively long period of time. In the meantime several meetings amongst the workshop participants have been held to explore these possibilities.

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Evolvability of Personal Learning Environments

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ABSTRACT

We review the concepts of Darwinian evolution and evolvability, and discuss the extent to which these can be brought to bear on the problems of personal learning environments (PLEs). While it is problematic to identify an evolving population of *individuals* (a definitional requisite of Darwinian evolution) in artifacts, we suggest an instance of a PLE system as fielded can play the role of individual in this seting, while configuration, code and component organization can play the role of *inheritable genetic information*. Also discussed are adaptivitiy, plasticity, robustness, and evolvability in this setting, as well as the role of *sex* (transfer of inheritable information from one individual to another) in providing plasticity in a community of use in the context of changing requirements.

Keywords

Evolvability, Sex, Personal learning environment, Plasticity, Darwinian evolution.

1. INTRODUCTION: DARWINAN EVOLUTION AND EVOLVABILITY FOR ARTIFACTS?

To what extent does it make sense to apply the biological notion of evolution to artifacts like software systems? Darwinian evolution is a process undergone by a changing population of individuals, in a 'struggle for existence' in which better adapted variants are more likely to survive, reproduce, and have their character traits persist beyond the lifespan of single individuals. The Darwin-Wallace theory of evolution has revolutionized Biology. It has even given philosophers a way to explain 'purpose' and 'meaning' within a mechanistic framework. And it has given rise to effective methods to apply these ideas to the automatic design of artificial systems, ranging from engineering optimization, to aeronautic, architectural and even artistic design by instantiations of principles (or axioms) that capture essential aspects of such dynamical processes, and has even been applied to the design of pharmaceuticals and of molecules with particular enzyme-like properties. Entire areas of computer science such as genetic algorithms and evolutionary computation have grown up to exploit this; and the evolvability of Darwinian processes and how it can be supported is a vibrant area of inquiry for both natural and artificial evolutionary processes.

This impressive success of Darwinian theory in this areas suggests that there might similar dynamics in other areas such as the 'evolution' of ideas, tools, artifacts, culture, or software systems. But does it actually make sense to apply Darwinian terms such as 'fitness' and 'evolvability' in these settings? To what extent are the axioms of Darwinian theory valid or even interpretable in these domains? Does the theory have any explanatory or predictive power and can it guide us in our design of artifacts and software systems? What about interactive systems that humans use in contexts of changing requirements? – here human beings play special roles in the mechanisms of inheritance, variability and in any notion of fitness.

We have been exploring the problems and issues that arise with attempting to apply the theory of evolution to realms outside biology. Key issues and pitfalls preventing the direct application of Darwinian dynamics to other domains are the identification of individuals (members of a population on which the dynamics operates) and the inheritability of fitness by offspring. Despite these difficulties and the divergences with biological evolution, and further research needed into evolvability in all domains, one can identify an entire array of important parallels and concepts from biological evolution which are or can be used to inform the design of adaptive, interactive artifacts and software systems.

2. SCALES OF PERSISTENCE AND HEREDITY

Darwinian evolution systems are comprised by populations of individuals undergoing processes of inheritance (in producing offspring) , variation and selection. If individuals cannot be clearly identified then application of this theory is not likely to be conducted rigorously. However, weaker analogues of evolution occur on a spectrum in which there is any sort of *descent with modification* on the one end, but evolving populations of individuals at the other along a scale toward full-blown Darwinian evolution:

- persistence without change, growth, or variation - e.g. of a stone existing without substantial change over a long period of geological time;

- growth and spread without variability, e.g. in the growth of crystals;
- persistence with growth and variation *(lifespan of single living things, maintained software and robotic systems, coral reefs, cities, and many other entities):* persistence and variability providing analogues of heritability but not actual reproduction;
- examples closer to biological evolution acting on populations but still lack well-defined self-reproducing individuals. e.g. design and cultural traditions, and generations of software releases;
- Darwinian evolution: heritable variability and fitness in populations of reproducing individual entities. E.g . organic biological evolution of life on earth.

3. FITNESS & EVOLVABILITY FOR SOFTWARE

Fitness and evolvability of software have multiple components which include:

- *Functional properties* (adaptedness to requirements and context of use)
- *Non-functional properties*
- *Variational / Lineage Properties* – capacity to vary / be varied robustly and adaptively
  [NB: The latter properties doe not effect the immediate fitness, but crucial to evolvability!]

4. SOFTWARE EVOLUTION, REQUIREMENTS CHANGE & EVOLVABILITY

In software engineering, change in requirements and context of use is the major factor in cost and impacts the areas of requirements engineering, software maintenance, and software evolution.

Evolvabilty for artifacts is the capacity of the systems, organizations and networks producing them to give rise to adaptive variants that flexibly meet changing requirements over the course of long-term change (Nehaniv et al. 2006).

Evolvability as a capacity to generate adaptive variability in tandem with continued persistence of software artifacts would be welcome in software engineering.

5. PLES AND APPLICATIONS TO SOFTWARE MAINTENANCE

As software maintenance costs exceeds 80% of all software costs, even small advances via the application of Darwinian theory to software could well result in the savings of billions or trillions of euros annually. One avenue worth exploring is the application of PLEs to support communities programmers and stakeholders in the creation and deployment of software, during the course software evolution and (inevitable) requirements change as contexts of use change. Conversely, PLEs themselves can be members of evolving populations whose evolvability and plasticity properties deserve the attention of those who build them or advocate their use in various settings.

6. SOFTWARE EVOLUTION ANALOGUES TO BIOLOGICAL EVOLUTION

Features identified in software evolution that may enhance evolvabilty (including maintainability and adaptivity to requirements changes) are the following:

- Re-use (not replication)
- Modularity (Parnas)
- Information Hiding
- Encapsulation
- Object-oriented “inheritance”
- Appropriate coupling and cohesion (Dijkstra, Parnas)
- Abstract Data Types (Goguen)
- Engineering for robustness to requirements change (e.g. Goguen, Berners-Lee)
- Dynamically configurable collections of interacting components (analogous to cellular organization) in differentiated multicellular dorganisms)

7. PERSONAL LEARNING ENVIRONMENTS (PLE) EVOLUTION & EVOLVABILITY IN A DARWINIAN FRAMEWORK

A suggestion for how to bring Personal Learning Environments into the Evolutionary Frame is to consider:

- PLE ‘system as fielded’ (instance) could be considered an *individual.*
- A system as fielded persists through time, although it may change, into a new fielded system due to adding or removing components, etc., this results in descent with modification which can be viewed either as a case of (*vertical) heredity* or as the *development* of an individual over time.
- *Inheritance:* its lines of code or, better, its constituent modules might be considered as ‘genes’ (potentially inheritable – re-useable – in other PLEs, and could be copied or imitated by new fielded instances of PLEs).
- Variation: (1) customization of a generic software product via parameters and installation, components options / apps; (2) copying / sharing from others’ PLE settings. Change in context of use and thus changing interactions and requirements will provide *phenotypic variation* that must be supported by *phenotypic plasticity*, the capacity to adapt and change robustly.
- Iteratively adapted by users to learning context & changing requirements -> evolution
- Capability to generate adapted organizational instances adapted to the current user requirements: *evolvabilty of PLEs*

8. SEX: THE TRANSFER OF INHERITABLE MATERAIL

Sex in the biological sense in evolutionary theory, is the exchange or transfer of heritable genetic material from one individual to another one. It is well known in evolutionary studies for its potential to increase the rate of evolution by creating variation.

Copying configuration or component organization from one or more PLEs to an existing PLE system, or creating a new with this inheritable information from several PLEs constitute natural and potential very useful examples of sex.

Note that genetic variability via sex in PLEs will in large part be driven by human preferences and choices, as well as fashions and trends. Communities of practice will share basic skeletal configurations and costumize these by learning what components to bring in from other members of social communities that share practices. Sharing such configuration information and component organization is thus a pervasive form of sex in PLE evolution.

9. ACKNOWLEDGMENTS

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Survival of the Fittest – Utilization of Natural Selection Mechanisms for Improving PLE

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ABSTRACT

In the current ongoing work we propose the use of tracking and feedback mechanisms in order to improve our Personal Learning Environment (PLE), officially launched in October 2010. The approach can be seen as a necessary prerequisite similar to the darwinistic model of evolution. This means the implemented widgets will be improved (variation) and removed (selection) according to the observations. This paper will describe the backgrounds, methods and some details of the technical implementation.

Categories and Subject Descriptors

H.5.2 (D.2.2, H.1.2) **[User Interfaces],** D.2.4 [**Software/Program Verification**].

General Terms

Measurement, Design, Experimentation.

Keywords

PLE, Widget, User Experience, HCI.

1. INTRODUCTION

Variation and selection are important mechanisms in the evolutionary development of organismal life forms. These mechanisms were extensively examined and described by Charles Darwin in his famous book on the topic [6]. He argues that there is an advantage in the probability to survive for these individuals and populations which are able to adapt better to their environment. This is described as fitness or 'Survival of the fittest'. Darwin's theory was later used as base for the so called evolutionary algorithms (EA), which represent a certain class of optimization algorithms, able to solve nonlinear, discontinuous and even multimodal problems. Evolution itself is a very efficient optimization process, which is able to adapt even pretty complex organisms to a changing environment in a very short time.

Ernst Mayr, who developed the synthetic theory of evolution, states that the natural selection is rather a selection process but an elimination process. Thereby less adapted individuals of every generation are terminated, while better adapted ones will have a higher probability to survive [7].

The interesting question is how evolution theory can help us in the development of a Personal Learning Environment (PLE). First of all the concept of PLE is still a new and vaguely explored concept. From an evolutionary point of view it could be considered as a new species conquering a still undetermined territory in an eLearning environment. There is no guarantee of success resp. survival of the species. More technical it could be considered as optimization process with undefined specifications how to solve the problem of helping the learner to overcome the challenge of managing distributed and potentially unknown but useful Web resources and Web applications.

The biological evolution would approach this problem by choosing the r-strategy, which succeeds by a high (r)eproduction rate. This strategy can usually be found when a species conquers new space. In case of the PLE we need two different views on the evolution metaphor, in order to fully apply this strategy. The first view is **macro evolutional**, concerning the development of PLEs as a 'species'. The question here is about finding the most appropriate form, which includes the programming language, deployment, user interface metaphors and value within eLearning environments (e.g. is it just a link list in an iPhone app or a full grown web desktop). Therefore a long-time 'survival' of the concept PLE would imply the development of many different individual solutions in a short period time. The second view to adopt is the **micro evolutional** view. In this view the functional elements of a single PLE solution are considered be individuals, struggling to 'survive' within the PLE. This view solves the question of adaptation to the user's needs on a functional level. Which resources are really needed, which functions are necessary, which are rarely used and which are never used?

A first prototype of a Personal Learning Environment (PLE) has been developed and launched in October 2010 at Graz University of Technology (TU Graz) [1]. Following the main PLE concept it aims to provide different learning and teaching resources, which can be personalized by each learner. Learners can decide if they like to use an application or not and build their own individual learning environment. This paper will outline our current research and development of a PLE.

2. Theoretical foundations

2.1 Evolutional considerations applied

In order to apply evolutional thinking, it will be necessary to establish the metaphorical links to the development of the PLE. The links will be mostly done on afore mentioned micro evolutional level, as this is more important to the specific development, however they can be adapted to the macro evolutional view easily. Evolution theory of natural selection uses the following relevant factors: reproduction rate and mortality (cycle for update, replacement and new widgets), population size (# of widgets), environmental capacity (max. # of widgets in the system and # of users using the widget).

In order to produce an evolutional pressure upon a population of individuals, it is necessary to have a limited resource. In our case there are actually two such resources driving the selection: a) the limited space within the PLE UI and b) the limited number of potential users. The first factor can also be described as growth regulated and limited by **population density**, which is depicted in fig.1. A population can't grow unlimited, as there are limited resources. The environment has a capacity, which is in our PLE case represented by the maximum number of widgets.

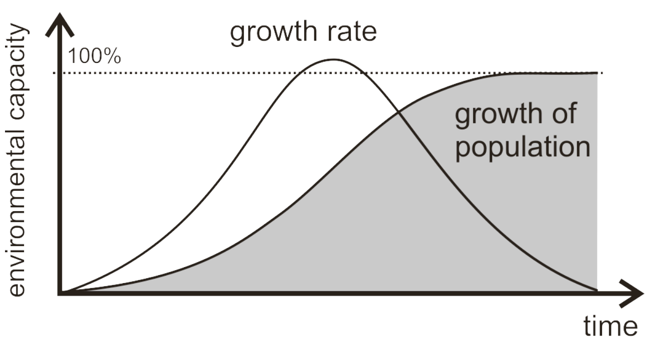

Figure 1. Growth regulation by population density

The second factor b) can be operationalized as selection criteria by asking the questions: 'Which widget draws the attention of the most users?' and 'Which widget has the biggest frequency of usage?' [8].

2.2 Selection

So the individuals of a population are forced into a constant competition for a certain resource against each other and against potential harmful conditions of the environment, producing variations for better adaptation. The different probabilities for survival are the base of the selection mechanism. Indeed selection is the main controller for the search direction within the evolutional optimization process. In biological systems it would determine which phenotypes reproduce at a higher rate. Phenotype describes the amount of all observable characteristics of an individual, expressed by its genes and influence from its environment at a certain point of time. The natural selection is a non-deterministic process, as it's disturbed and interrupted by random events. Individuals can die, thereby the evolution loses information which could have represented an optimum solution (e.g. the Wikipedia widget is dismissed because the company offering the service wasn't able to raise enough funds). Environment and other contextual conditions are ever changing. According to Solbrig [9][10] there are three different modes of selection 1) stabilizing selection 2) disruptive selection and 3) directed selection. All these selection modes and evolutionary pressures aim at increasing the fitness of a population.

1) The stabilizing selection mode (as can be seen in fig.2) describes that the evolutionary pressure of the environmental factors is directed at outliers, thus this mode favorites the average, which will result in a decrease of variability within the population.

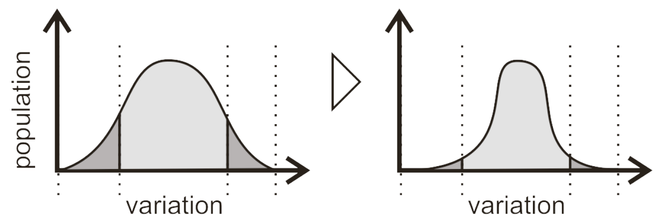

Figure 2. Stabilizing selection on the distribution of population

Stabilizing selection on micro evolutional level can be done by analyzing which functions, respectively widgets in the system are hardly or never used. On a macro evolutional level it would mean to discontinue 'excotic' PLE solutions.

2) The disruptive selection mode (as can be seen in fig.3) is directed against the average, reinforcing the extremes, thus splitting a population into two new species. Since our population (on micro evolutional level) is the quantity of widgets, the development path would split and result in two new different solutions for a PLE. On the macro evolutional level this would mean to dismiss the core idea of a PLE, while generating new concepts.

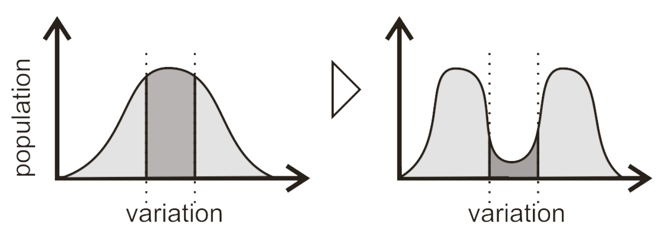

Figure 3. Disruptive selection on the distribution of population

3) The directed selection mode (as can be seen in fig.4) can be found in natural populations quite often. Thereby the selection works only against individuals on one side of the distribution, moving the curve to a new optimum. This mode can also be found when the PLE developers define new functions and user requirements, resp. conceptual decisions (e.g. we will only support intranet applications).

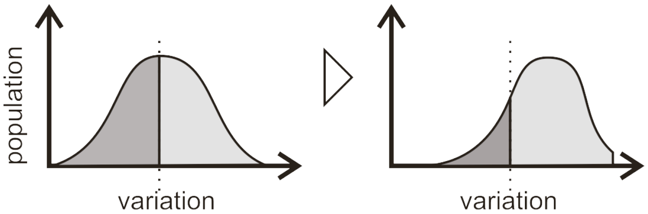

Figure 4. Directed selection on the distribution of population

2.3 r/K selection theory

The terminology of r/K-selection was defined by the ecologists Robert MacArthur and E. O. Wilson [11][12]. The r/K selection theory states that in the evolution of ecology two major strategic approaches for reproduction can be found, aiming to increase the fitness of a species. The strategies are basically a tradeoff between **quality and quantity of the offspring**.
Thereby increased quality come with a corresponding increase in parental nurture, while a focus on quantity would decrease the amount of parental investment. Each of the strategies is designed for specific environmental constraints. It is also possible that a species changes the strategy due to a change in the environment (e.g. the ecosystem becoming stable for period of time). However in nature many different mixed forms of these strategies can be found. In long terms the k-strategy will always be superior, which means that quality succeeds in the long run over quantity.

The r-selection strategy (also referred to as r-strategy) succeeds in unpredictable, unstable environments. It is especially useful when it comes to conquer a new unknown ecosystem. It would be a waste of energy and time to adapt to circumstances which are still unknown and will most likely change again. Therefore the r-strategy is characterized by a high reproduction rate and short lifespan (see fig.5). Transporting this to the PLE would mean to provide a mass of functions (in our case widgets) without looking for quality in the first instance.

The K-selection strategy (also referred to a K-strategy) succeeds in stable, predictable environments and describes a growth which is ruled by population density, usually constant and close to the maximum capacity of the environment. The adaption process is slower but the lifespan is longer and it fills more effective the environmental niche. In case of a PLE the application of this strategy could mean the increase of quality of a single widget, due to several update cycles, thus adapting optimal to the user's needs.

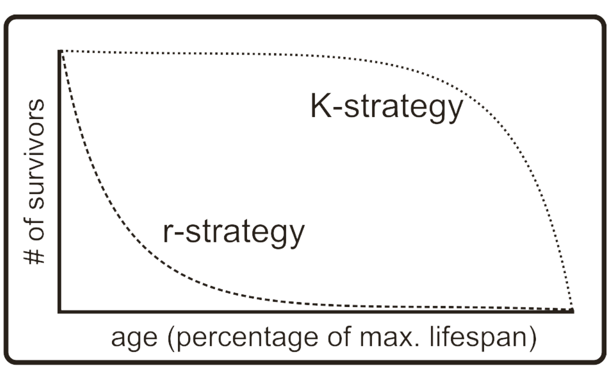

Figure 5. Depicting the relation between fitness and age for r/k

In the example of our PLE we also use a mixed approach. With the beta 'generation' of the PLE a bunch of widgets was provided. These widgets were then tested for usability issues, corrected and deployed in the first generation. Last semester a class of students programmed additional widgets in order to produce a certain quantity of functions for the users. So the first and the second generation can be seen as mostly r-strategic. The update process will be repeated on an annual basis. Most of the students last semester chose to produce new widgets, while some reused and optimized existing code (which in turn can be considered K-strategic).

2.4 Variation

The term variation in the evolutional context is usually described as shift in the genotype or genomic sequence. These shifts occur through a) mutation and b) recombination and generate new phenotypes with different probabilities for survival.

a) Mutation is a random process, aiming only at the generation of new alternatives. Mutation can result in different types of change in DNA sequences. It can have either no effect, altering the product of a gene, or prevent the gene from functioning properly or completely [13]. According to the optimization theory, mutation would be considered as a mechanism to overcome local optima. Which means the evolution doesn't stop if everything seems to be nicely adapted. There is still potential to explore new variants. In case of PLE development mutation can be considered as slight updates of existing code or UI elements.

b) Recombination
Recombination is also referred to as cross-over. The process is working somewhere between mutation and selection, thereby combining and distributing genetic material (DNA, RNA) in a new way. There's a random process determining the points where crossovers occur, however recombination is not a random process like mutation, as the recombination itself is not random. This means that the probability is low to separate genes that are close together or functional linked.

The code to all widgets in our PLE is open source and so far all widgets are open for variations by future developers. An open source policy and continuous development, resp. variation are a necessity for the 'species' PLE to finally succeed.

2.5 Technical Implementation

The basic architecture of the PLE is a mashup [4] of widgets. For each service a widget is provided that follows an extension of the W3C widget specifications [5]. The PLE, its requirements and its technological concept are described in detail in MUPPLE09 workshop [3]. Fig. 6 shows the general concept of the PLE as it is used at Graz University of Technology. The concept follows the idea to bring together university wide services with applications on the World Wide Web.

The implemented first prototype of PLE offers centralized access to various University services [1], like administration system: TUGraz online, LMS: TU Graz TeachCenter (TUGTC) or blogospheres: TU Graz LearnLand (TUGLL) [14] in one overview. The users can personalize the PLE to their individual information and learning needs. In addition, public services on

WWW are also offered in the PLE. For each of these services, a widget has been developed that can be integrated into the PLE.

Widgets are small embeddable applications that can be included in an HTML-based web page or executed on the desktop. This client side code can be a simple JavaScript, Java-applets or what ever can be embedded in a valid HTML or XHTML document. It contains the functionality to build the GUI of the widget dynamically and the logic to retrieve or update data from services provided by the PLE server as well as remote servers. The mashup of widgets used in PLE can be classified to end-user mashups as described in [15]. The PLE contains a widget engine, implemented in Palette project [16] to load and handle the widgets according to the W3C widget specifications. While the data extraction is carried out on the server side, the data flow and presentation components are handled by the widget engine on the client side.

Fig.6 shows a conceptual view of the PLE first prototype that integrates university portals and some other Internet services.

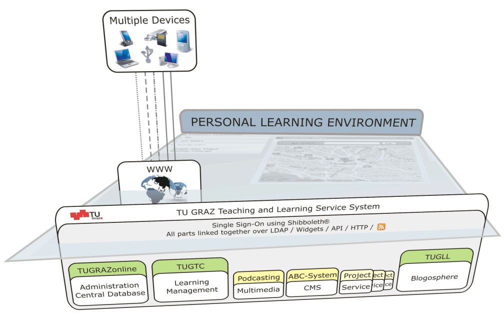

Figure 6. PLE concept at TU Graz. Mashup of distributed applications and resources from the university and the WWW.

2.6 User Interface Structure

There are many e-Learning services that are already provided by the TU Graz, including course administrations in TUGraz online, course learning materials such as e-books, podcasts etc. in TUGTC and user generated contents as well as user contributions such as blogs, bookmarks and files posts in TUGLL.
All these services are going to be integrated in the PLE as widgets. Therefore it was necessary to design a coherent GUI to avoid the possible usability and consistency problems that may occur [3]. The PLE GUI (see fig.7) is a combination of a traditional UI with a sidebar element and banner for orientation and navigation. In addition, it offers a widget-based UI with the so-called ”widget zones”, which require an adjustment by the user.

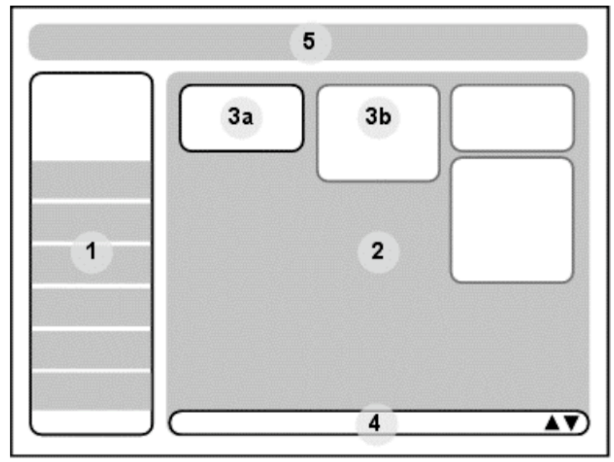

Figure 7. User Interface Structure

The PLE User Interface contains the following elements: 1) Sidebar elements contain widget topics. 2) Widget zone contains the widgets that belong to a widget topic. 3a and 3b) Widgets within the corresponding widget zone. 4) Hidden personal desktop containing a mash-up of widgets from different widget zones selected by the user. 5) Banner displays information in context of the active widget zone from the network.

2.6.1 Sidebar elements

Widgets are categorized according to pre-defined topics. Each widget topic (category) has its own widget zones. The sidebar elements contain the main widget topics and help the user to switch between widget zones. The topics are easily extendible if the number of widgets is increasing. Furthermore, it is planned that the sidebar also updates the user on the status of the widgets by means of color and numerical indicators. The sidebar can be switched off in favor of the unfamiliar widget-based UI and replaced by another navigation element, which resembles the Mac Dock menu on the bottom, left, top or right part of widget zones.

2.6.2 Widget Zone

The widget topics include different areas related to formal and informal learning, i.e. ”Communication Center” for emails, chats and news groups, ”TeachCenter” for all services related to the TU Graz LMS system TUGTC, such as course materials, podcasts etc., ”LearnLand” for services related to the TU Graz blogosphere system TUGLL social bookmarking, file sharing, etc. and ”Help and Support” for the help desk as well as Frequently Asked Questions (FAQ). These areas are called widget zones. Widget zones contain widgets and are structured in columns. The users can switch between widget zones, add, open, close, customize, position and arrange the widgets in different columns according to their personal learning preferences.

2.6.3 Widgets

The widgets consist of a front side and a rear side, where the rear side contains the widget preferences that can be modified by the user. If preferences must be changed, the desired widget can be flipped. By this applied flip-animation the users spatial perception is undisturbed and makes the GUI more understandable. There are two kinds of widgets a) system widgets and b) standard widgets.

2.6.4 Personal Desktop

The users are able to create a mash-up of the most frequently used interesting widgets from different widget zones in a special interface called "personal desktop". The personal desktop is always available to the user and can be activated at any time. When the user activates the personal desktop it overlays the whole screen from the bottom of the page upwards (see figure 4.2 part 4). The user can add or remove widgets from all widget zones to his personal desktop and arrange them in columns according to his personal taste.

From the very beginning, an appropriate and good usability of the TU Graz PLE interface was one of the main objectives in the development process. Therefore during the implementation of the first prototype several usability tests were conducted, including heuristic evaluation and thinking aloud tests. The results were integrated and deployed in the current version.

3. Hypothesis

Tracking user behavior, respectively the usage of individual widgets in combination with a feedback mechanism will provide empirical evidence for adaptive development.

Following an evolutional model of developing the PLE, this will mean a stepwise improvement and rejection of individual widgets in further iterations of the development cycle.

4. Methods and Materials

In order to improve the PLE we needed to consider different parameters that influence the attractiveness and effectiveness of the whole system in general as well as individual widgets. To meet this goal a tracking module was implemented to measure quantitatively how often the widgets are used and by how many users. The measurement was operationalized by the means of tracking individual and overall usage of widgets. In order to measure the usage of widgets a hidden module in the background tracked the users' active widgets.

The widgets that are used in PLE can be classified to three categories depending on how they interact with other services and applications on World Wide Web (WWW).

- Widgets that have no interactions with WWW such as widgets representing learning objects.
- Widgets that have a server side component to preprocess the data on PLE server such as widgets that integrate university services in PLE.
- Widgets that use the PLE built-in proxy to request data from remote services such as RSS FEED reader widget.

The client-side tracking module is added to the PLE widget engine to provide widgets including the possibility to offer information about user behavior on the client side. In periodic intervals the information (if any) is captured from all activated widgets in PLE and sent to the server-side tracking module for further processing. The server-side tracking module is used also for second and third widget types to capture information related to the user behavior in widgets depending on the data traffic on the server side.

At the current state of the PLE development there are 912 users in the system, whereof almost 30% can be said to use the PLE. In the last semester a group of students developed new widgets, in order to provide additional functionality as well as improving widgets from the previous beta stage. The system was introduced to the students in October 2010. The Tracking module was active since 1st of November 2010. At the current date this is 102 days.

5. Discussion

First the acquired data seem not sufficient to draw any clean conclusions for improvement. As the feedback module wasn't implemented yet, there is no chance of getting qualitative feedback, without performing another usability test. The analyzed data are purely quantitative. Nevertheless from the number of users, who have installed a certain widget, we are able to determine to top 5 used widgets out of the 30 provided. Actually theses top 5 are about the universities eLearning services, a mail widget and a system widget for changing the color styles of the interface (tugWidget, tccourses, tugllBlogs, mail, changeThemecolor). Within the top10 we find further a newsgroup reader, a game, google maps, facebook and the leo dictionary. From an educational point of view these choices make perfectly sense as these services are well known and frequently used even without the PLE.

Interestingly the most installed widgets are not necessarily the most used ones. The top 5 with the highest usage rate include weather forecast, rss reader, twitter, TUG library widget and again the leo dictionary. Within the top 10 we find here again google maps, Facebook and tugllBlogs, beside another dictionary and a currency converter.

Within the last update cycle, resp. the time when the students course developed new widgets, the weather widget was replaced by a new version. Actually this can be seen our current update strategy. If the outcome of the variation is a widget that fulfills a function better, then the old one will be replaced.

6. Conclusion and future works

According to the hypothesis we expected to get more knowledge about user behavior, user preferences and derive data, which would help us to differentiate user behaviors, for instance between students of first and last semesters or students of different major of studies, and finally to improve the system in a natural way by variation and selection. However due to lacking qualitative data we are not able to falsify the hypothesis.

In order to gather qualitative measures of the user experience (UX) in future versions, a rating system will be implemented. This will be done either by a 5 star rating system or alternatively by a small feedback questionnaire contained in every widget, which consists of less than ten items of semantic differentials inspecting the UX quality of the widget, respectively important variables of evolvability. These would be attractiveness, dependability and perceived effectiveness. The semantic differentials will be taken from the reliable UEQ inventor constructed by [2]. The fig. 2 depicts the questionnaire integrated into the widgets backside.

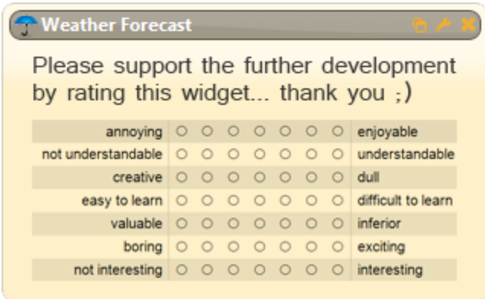

Figure 2. Mockup of questionnaire integrated into the widget GUI for qualitative measures of the user experience.

In our PLE users can select some widgets from a widget pool and activate them for personal use. However if the user activates some widgets it does not necessarily mean that these widgets are actively used. In future versions the tracking module might be able to detect an active widget usage und track the usage in detail as deeply as possible.

In future works it would also be interesting to classify users according to their individual needs, for instance users who use more often only widgets with a strong focus on communication or users who use PLE more for learning issues, etc.

In order to meet data privacy considerations, we will implement a disclaimer, or terms of service (TOS) which needs to be agreed by the users once in order to use the PLE.

The tracking module provides sufficient quantitative data about the usage of the widgets. Bearing in mind that more knowledge about the learner will help in designing didactical models for providing learning courses, data gathering must be seen as a first valuable step. Furthermore these data combined with user profiles will be a precondition for building a recommender system on learning objects within PLE.

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Virtual Learning Places: A Perspective on Future Learning Environments and Experiences

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ABSTRACT
In this paper, I go through the evolution of the learning environments to justify the need for Virtual Learning Places (VLP). I also describe, briefly, the design principle that are inspiring the development of a concrete realization of a VLP - LIFE - and the open challenge on which we are currently working on: a) the ecological monitoring of the experience and of the experience styles; b) the promotion of a Design literacy.

Categories and Subject description
H.5 INFORMATION INTERFACES AND PRESENTATION. H.5.2 **[User Interfaces**]; H.5.m [**Miscellaneous**]; K.3.1 [**Computer and Information Science Education**]: Distance learning; K.3.2 [**Computer and Information Science Education**]: Computer science education, Information systems education.

General Terms
TEL, Design, Experience

Keywords
Virtual Learning Environment, Personal Learning Environment, Virtual Learning Place, DULP, Learning as experience, Experience's dimensions, Experience's styles, Design literacy, Ecological Monitoring of the experience, LIFE

1. ONCE UPON THE TIME A KING CALLED "COURSE" ...
Long before "Technology Enhanced Learning" became popular, at the time the "web" had just taken off and everyone was enthusiastic about "e-learning", the technological solutions proposed to realize on-line learning processes relied on the so-called CMSs (Content Management Systems), and were basically identified with them. A fact that indicates how the focus of learning - in this case we cannot use the term "education" - was the *content*. Next step was the substitution of CMSs with LMSs (Learning Management Systems), "familiarly" called *platforms* that allowed to aggregate and organize contents along timelines and paths of sense, i.e. to organize and deliver courses and modules, accompaning them with periodic assessments and, eventually, evaluations. During the years, such deterministic vision of learning, that perfectly matched with a "corporate" vision of education, seeking mainly to optimize costs and efficiency of the learning processes, produced a plethora of "markers" (called *tags*) aimed to promote a standardized description, representation and delivering of contents and processes [1]. Educators, on the other hands, since the beginning, perceived such vision as inattentive to the pedagogical reasons. For educators, indeed, flexibility is a vital factor, on many different levels: methodological, procedural, of vision, content.

It was during such climate of transformation that were introduced the so-called VLE (Virtual Learning Environment), some of which [2] over time reached a widespread diffusion thanks to the adoption of open-source strategies. Such environments, supported by considerably large communities of developers and users, have met, and continue to meet, needs and expectations that basic stakeholders (e.g. school educators) have about the technological support/enhancements to learning. The reason for this lies mainly in the still limited diffusion of a reasonable level of media, technological and techno-pedagogical literacies that, in turn, results in a preference for tools that allow one to replicate and to amplify activities usually carried on during learning processes they used to deliver face to face. Despite many attempts to update the VLEs with new features that, in the statements of the developers, should serve to support more open and collaborative educational processes, such environments remain basically LMS - centered on the object *course* - whose design and development are guided by the beacons of standardization and efficiency in the delivery of content. Inevitably, such a design philosophy stumbles in the following critical remarks:

- the structure of the platform is designed to create watertight compartments, coincident with the courses/modules, that do not foresee shared spaces; watertight compartments to which the process' manager may aggregate, as attributes of the *module*, all sort of constituent and functional elements which contribute to define a typical learning process: teachers, learners, contents, forum, chat, assessment module, etc. ...);

- relations are asymmetric and favor the maintenance of the roles that characterize traditional teaching processes (e.g. teacher and student);
- lack of efficient mechanisms to share and export content (Learning Objects, LO, have no relevance in the world of informal peer-to-peer exchanges); hence a weak interrelation with the "world" outside a specific training process, due to: i) poor external visibility of the outcomes produced during the training process, ii) a limited time windows within which students have access to contents and activities with a consequent weakening of the learning community, iii) lack of interrelation between different training processes.

From the pedagogical point of view, moreover, the design of the traditional VLE has been criticized [3], especially by those who deal with Life Long Learning, LLL for two main reasons:

- lack of attention to learning as social practice focused on dialogic exchange (including collaborative and cooperative ones) tends to prevent the transformation of tacit knowledge into explicit knowledge and, thus, its transfer/application outside the narrow confines of a given training process;
- the close structure of the traditional VLEs tend to prevent or slow down the construction of the virtual identity of individuals that, indeed, is one of the main objectives of people involved in LLL (and that led to the adoption of instruments such, for example, the e-portfolio [4]).

2. THE REVOLUTION: STUDENTS AS MANAGERS OF ENVIRONMENTS, PROCESSES AND CARRIERS

Over the years we observed an astonishingly rapid transformation in the way people approaches the web and in the social practices hosted in there. Such phenomena are evident at most among the youngest generations [5] and, probably, are producing a modification of their brain-frame and, therefore, way to learn. Among the most evident transformations and trends:

a) the tendency towards a more limited use of e-mail, due to the heavy "pollution" suffered by this communication channel because of the spamming and to its lack of immediacy in the construction of groups of discussion; unless, then, increase the demand for e-mail notifications to avoid presiding tents of socializing places, many of which are actually desert (the main goal of the greatest part of their inhabitants, in fact, is to appear rather than participate actively to the social exchanges);

b) a flood of instant communication channels (eg. Twitter) that at present integrate also easy ways to exchange data in real time (Messenger) and/or voice interaction (Skype); all such communication channels favor a one-to-one emotionally dense interaction that, usually, takes place between members of small communities (easy to create thanks to simple and rapid procedures for links aggregation);

c) an explosion of blogs and personal websites through which individuals satisfy their need to act as protagonists of the great game of internet, even if, in reality, except for a few cases, everything reduces to the publication of personal diaries written to the advantage of few members of small communities of bloggers - easily identifiable from the list of the linked blogs - and/or friends;

d) a continuous development of new web services which include, inter alia, a plethora of social systems for publishing and sharing contents - link (de.licio.us), images (flickr), video (youtube), etc. - that have become real "must"; showcases where one should appear and to which one has to refer, for example, from their blogs, often used, right now, as pseudo-aggregators; these social and personal media are causing a so relevant crisis of the traditional ones that nowadays the "strategic planning" departments of the advertising agencies includes in their strategies synergistic use of the social environments ("viral advertisement") in order to boost the effectiveness of their traditional campaigns of "advertisement";

e) the increasing availability of atoms of information that can be easily captured by special aggregators able to raise their level of dissemination and social sharing;

f) the widespread use of folksonomies that as spontaneous emergencies (bottom-up approach) represent a valid alternative to traditional ontologies (top-down approach);

The above transformations induced a certain number of TEL's experts to theorize the deconstruction of traditional VLEs to give all students the possibility to build up and manage their own learning environment, content and process. Such position intercepted a diffuse desire for more open social interactions and for a greater independence in determining their own destiny. In some sense it can be seen as a revised version of the naturalistic approach to learning and led to the concepting of a new typology of learning environments: the PLE (Personal Learning Environment) [6], services and content aggregators that can be freely and fully reconfigured by individuals.

Of course, the management of a PLE would require:

- considerable critical skills to be able to select contents and services;
- pedagogical skills to be able to design their own educational path;
- sufficient motivation to respect a self-defined time-

schedule;

- ability to interact socially not only within their own PLE, but also on those of others, to contribute to the collaborative production of content.
- It is quite evident that all the above skills cannot be found all together in a single individual at any age. Perhaps they could in part emerge as a characteristic of what we may define, using an oxymoron, the "collective-connective individual" but, undoubtedly, remain the following critical issues:
- the difficulty to produce "sense" from an ensemble of limited information (such as those derived from RSS) and to filter resources potentially of the same order of the size of the web;
- the difficulty of extracting significant "patterns" from the "chaos" of internet, that may make very hard to manage the trajectories of any educational process;
- theencouragement of what we call "territorial individualism", whose outcome is the production of weak aggregates, or virtual non-places [7,8] i.e. places that have no peculiar characteristics and that may easily lead also to live "non-experience"

Not to be misunderstood, I would like to stress that the production of non-virtual places is dangerous not because it questions the existence of training agencies, but because, it prevents the stratification of the memory. This latter is the process that drives the transformation of a physical space in a "place" [9] where it is worth to live.

The challenge for the future, thus, in our opinion, is not the transition from VLE to PLE, but, rather the construction of virtual "places" that from one hand allow the osmosis of contents and people and, on the other, manage to maintain a high degree of recognizability and attractiveness: i.e. interconnected organisms able to reconfigure themselves, while maintaining their own identity, and to expand into the everyday life, far beyond the boundaries of the "virtual". In the DULP perspective [10, 11] we call such places: "liquid learning places"

3. AN OLD BUT ALWAYS NEW AND ALTERNATIVE PERSPECTIVE: EDUCATION AS EXPERIENCE ... AND ITS STRATIFICATION

In a whatever complex framework the liquidity becomes a dominant characteristic of the system that can be viewed either as a pathological condition [12] or as an opportunity [10] to restart, for example from a renewed attention to the individual, not considered any longer as "user" but, rather, as "person" wishing to use the mediated communication to add "sense" to her/his education through the immersion in meaningful experiences, supported by the presence of a discrete machine.

Refocusing on the individual means recover her/his motivation and putting her/him in a position to develop a critical attitude to analyze the "fluid" in which s/he is immersed, to identify significant relationships that might allow her/him to design her/his own experencial trajectory. It means also to ensure that such experiences can sediment and stratify to make "places", included virtual ones, recognizable. It means, as well, to ensure that all dimensions of the experience benefit of the same level of attention.

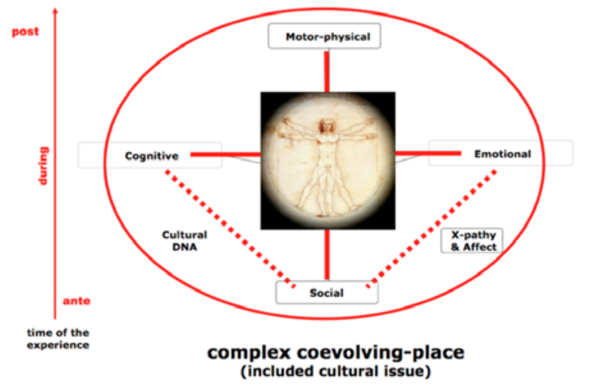

Figure 1 - Representation of the time scale and of the interaction levels involved in an experience

By the way, which are the characteristics of a personal experience (including educational ones) that can be considered universal and meaningful?

We do think [13] that the definition of the multidimensional space of the personal experiences may derive from the integration of:

a) personal characteristics;
b) dimensions of the human interaction;
c) any further dimension that can help to describe, in a manner as complete as possible, an "experience"

"Experiences", indeed, are complex processes based on interactions, or communicative acts, that operate simultaneously on multiple levels, the main fuels being the personal motivation, possibly supported and/or amplified by a general curiosity or specific expectations (grounded in your own mental models).

In Figure 1 we have schematically summarized the characteristics of the human communication that, of course, are also the basis of all activities experienced by the individuals:

i) the four levels of interaction - physical-motor, cognitive, social and emotional - that when combined may produce further dependent dimensions, e.g. the combination of social and emotional levels produces affect & x-pathy (i.e. sym-pathy, uni-pathy , em-pathy), while the combination of cognitive and social levels leads to the definition and stratification of the culture, i.e. the codified DNA that makes a place (included virtual ones) recognizable:

ii) the continuos coevolution of individuals and environment;

iii) the temporal dimension, either objective and subjective

The equivalence between educational processes and experiences, which has strong historical roots [14], demands also for the identification of a universal process able to incorporates and reproduces the essential features of every kind of activities. To this end we have tried to identify those features that characterize the behavior of all organisms of any degree of complexity; the outcome was the design of the organic processes (OP) [15], a process based on three parallel layer of functionalities:

- explore: the environment to collect information & learn;
- elaborate: the information to design/produce;
- communicate: the "products" by means of "actions" that, in the case of very complex organisms, can make use also of highly structured and conventional languages

The correlation of the descriptive multidimensional space of the personal experience with the organic processes led us [13] to obtain the framework of Table 1which defines a set of "experience styles" and their relationship with each of the three functional layers of the process.

To the 'explore/learn' layer are associated the perceptual preferences of the individual; for example, the preferences about specific sensorial channels of input, or about the media through which communicate (images, text, sounds, etc.). Each of such preferences, then, may be further detailed by specifying what we call 'exploring styles' (used to visualize images, to read, to listen, to handle, etc.) [16] The first layer of the OP is certainly related to the physical level of interaction and, inevitably, also to the cognitive one, for what concern attention, memory, interpretative strategies, self-control, etc. More or less all these elements involve the emotional level too, and emotions, as well known, affect the sensory inputs also because of individual inclinations toward specific emotional nuances. Actually all levels of the human interaction (see Figure 1) are involved in each layer of the OP although each one at a different intensity, even null sometimes.

To the 'elaborate/design' layer belong personal styles used to process the information (e.g. analytical and sequential or intuitive and global [17], influence of emotion, etc.), to work (active or reflective, individual or collaborative) and to design (abstract or concrete, inclinations toward creativity, divergence and innovation). The prevailing interaction level in this layer is no doubt the cognitive one that can be more or less 'colored' by emotional and social implications.

The third layer of the OP, 'actuate/communicate', can be related to the inclinations of individuals toward extroversion/introversion, combined with their preferences regarding mode of social interaction and communication that, of course, may partially overlap perceptual preferences (do, say, write, produce images, etc.) and depend strongly on the ability to interact emotionally.

As shown in Figure 1 there is at least one "horizontal" dimension of the "experience" that cannot be neglected in defining the "experience styles": time. The 'ante', 'during' and 'post' of an "experience", regardless of their objective value, are often perceived in a very subjective manner. The subjectivity of the experience shows itself either at the perceptual level (duration of time intervals), as differences in the expectations about an experience and, as well, in its memory. The subjectivity of the time dimension is clearly related also to motivation.

Another cross-cutting dimension of the "experience" is the ludic one, related to the propensity of individuals to play. Although not completely independent of the other styles discussed above, it adds to the overall picture the inclinations of individuals toward 'alea', competition ('agon'), vertigo ('ilinx') and 'mimicry' [18].

Although the one described here is a reasonable framework, we would like, anyway, to stress that the

Table 1

		Experience Styles					
				Interact.			
Organic Process	Explore Learning	motivational	perceptive (exploring)	physical cognitive interaction		subjective time	ludic (alea, ilinx, mimicry, agon)
	Elaborate Design		info processing, working, design	cognitive emotional,socia l interaction	creative, innovative		
	Actuate Communicate		extroversion introversion	social, emotional, cognitive			

identification of all the dimensions of the "experience" is still a very open issue.

To conclude this paragraph I would like to underline that the above descriptive model of an experience should be considered as an ideal one because does not take into account constrains/limits that may be introduced by machines/systems that are involved in the mediation of the experience. Indeed only rarely such mediation can be defined ecological, transparent; almost ever the mediation introduce filters that modify the relevance of the various dimensions of the experience. Of course one has to put enough care in distinguish between filters' effect and truly relevance of the experience's dimensions.

4. BUT IN PRACTICE? LIFE

We started to put in practice the above considerations by designing and developing a Virtual Learning Place called LIFE (Learning in Interactive Framework to Experience) [19], with the intention to [20]:

- favor the grow and stratification of the learning "place", i.e. what can be considered as the basis for the construction of the identity and the cultural DNA of a society, although virtual one;

- encourage the development of meaningful social interactions and the co-construction of knowledge, by paying attention to restore appropriate symmetric relationships and equal possibilities in knowledge production;

- support the development of virtual identity and personal growth of individuals, thanks to tools designed to valorize their personal characteristics and, at the same time, their ability to behave as social actors;

- provide simple ways to import, export and aggregate data;

- offer the maximum pedagogical flexibility, in order to support any sort of learning process (included the 'organic' one) and any BC[3] (behaviorism, cognitivism, constructivism, connectivism) combination to better fit the needs of any specific context;

Taken for granted the inclusion of those tools that are used in a traditional VLE to manage learning processes and to publish relevant informations (tools that we do not discuss here), a "learning place" (LP) is characterized by the presence of two areas intended to support the development, respectively, of knowledge and of learning communities. These two areas must be closely interrelated because the outcomes of the activities of a learning community can and should be considered as candidates for enriching the cultural stratification of the place. The production of the collective efforts of a community cannot and should not disappear with the end of a given process or, for example, with the retirement of a given teacher. This is why one must provide easy mechanisms for "move" data between the various areas used as repository and/or aggregator of knowledge (e.g. maps, content cards, multimedia archives, etc.) and those areas characterized by more intense collective and knowledge production (e.g. design workshops, joint development of documents, forums, etc.).

At the same time, according to the dictates of the connectivism [21] it is very important that LPs are not closed on themselves but, rather, offer opportunities to expose their history, contents and sometime services - either through techniques of "syndication (e.g. RSS), or by XML markup, or API, or any other kind of future technology - and to import equivalent ones from the net. In fact, although the design and adoption of efficient mechanisms of data import-export is strategic to stimulate the co-construction of the "spirit of place", it is also reasonable to allow for a rapid access to all those sites that expose important aggregate of knowledge derived by collective efforts (e.g. Wikipedia, YouTube, etc.). To satisfy such need it is important to offer simple ways to aggregate, filter and represent contents. Unfortunately, to date, the standards developed in the field of education do not seem to satisfy these requirements and, thus, the expectations of basic stakeholders and operators of educational processes, and, in fact, are not used. It is certainly an issue on which one should meditate more deeply.

While we are approaching faster and faster a world in which everyone will be constantly connected to the net at a flat rate by means her/his own personal devices, there are still a considerable number of relevant scenarios within which it would be preferable to work off-line. This is why the LP, in the future, should be able also to export some content and services in a off-line usable format from desktops of laptops or mobile phones, through widgets and apps.

Another important aspect of the design for "learning place" is the attention that should be payed to support the personal experience of the place. In particular, it is important to make understand the actors that every act done during a collective activity can also be used to build their own digital identity. It is relevant, therefore, to offer personal environments/corners within which one can build her/his identity with as much as possible freedom and creativity, drawing from what is has been produced by the individuals within and outside the learning place.

At the end of this paragraph is worth noting that, in any case, support for the experiential dimensions lies only in part in the development of ad hoc tools/technologies, since the environment must be sufficiently flexible to accommodate any sort of educational process/experience. The experience is to be largely supported by the design process and its management, as well as by the motivation of individuals. Certainly it is necessary to offer a wide range of possibilities, in order to minimize the technological filtering we were referring to at the end of paragraph 3. For example, in order to promote the game dimension, we have developed a prototype of serious game engine [35]; to facilitate the acquisition of metacognitive skills we have developed a tool to design, also collaboratively, concept maps [22]; to encourage the development of design skills, we developed a tool to run a virtual show & tell [36], etc..

It is my deep conviction that technology should not reduce the educational processes to stereotypes but rather encourage: a) the acquisition of meta-design skills; b) provide tools for self-evaluation with respect to all dimensions of an experience, possibly in action; c) promote personalization and contextualization of educational processes.

To the first two themes are devoted the last two paragraphs of this article, while the third one will be dealt with in future papers to come.

5. PRESENT AND FUTURE CHALLENGE N.1: THE ECOLOGICAL MONITORING OF THE EXPERIENCE AND OF THE EXPERIENCE STYLES

One of the logical consequences of the increasingly complexity of the educational processes, like the "organic" one, is that assessment and evaluation should converge and integrate into the monitoring of the educational experience's qualities.

Being well aware of the objective difficulty to define the relevant qualities/dimensions of an experience and to assign them a corresponding reasonable weight with respect to the learning processes (see paragraph 3), we are, anyway, faced with the challenge to equip trainers, and students as well, with tools that may help them in the quantitative and qualitative monitoring of the activities carried on during such processes. A request that becomes even more stringent in on-line processes which lack multimodal face-to-face interaction.

Luckily, the educational processes mediated by the machine, like those taking place on-line or in blended configuration, generate copious amounts of electronic traces that, when properly filtered and analyzed, can serve to achieve our purposes.

Not by chance, in fact, whatever the tools and methodologies used, a shrewdness of those who design educational processes should be to pay attention that each activity leave at least some traces in a given place. Ideal from this point of view is the forum because it is particularly suited to collect analysis, brainstorming, storytelling, design diaries, etc..

Texts, in fact, are still the most common traces left by the learners during their training and, consequently, text analysis is still the most ecological way to obtain information on individuals, their socio-relational skills, the learning process.

Of course, once that traces have been collected we must ask ourselves what aspects and qualities of the educational experience we intend to monitor and which indicators are the most appropriate ones. This is a very challenging and quite new field of investigation!

In the past we have shown how monitor the cognitive evolution by mean of a quantitative evaluation of concept maps [22]; more recently we have shown that starting from an analysis of the interaction occurred in a forum it is possible to monitor the social and emotional characteristics of educative processes [23,24], by integrating social network analysis (SNA) [25] and automatic text analysis (ATA) [26] ... and the search for new monitoring methodologies and indicators, of course, goes on.

6. PRESENT AND FUTURE CHALLENGE N.2: DESIGN LITERACY

The acquisition of meta-design abilities requires first of all the spread of a sufficient level of "design literacy" among the new generations. Indeed in a situation dominated by the complexity the ability to design her/his own trajectory is assuming more and more a central relevance in education. As compared to the fluctuations that have characterized the history of education [14] - nature/culture, utopia/pragmatism, humanities/sciences, theoretical/practical activities - the central position of the Design, indeed, can be claimed [27] on many different levels:

i) pedagogical, for what concerns the purpose of educational processes; the ultimate aim, indeed, should be to enable students to acquire reflective and meta-design skills in order to be able to continuously redefine the design of processes and, even, their own project of life; in other words learners should be able to put into practice the critical method [28] that makes the so-called reflective practitioner [29] a sort of reference model in the complexity of contemporary society – renewing a tradition that from Socrates comes to date [11];

ii) process level, because the Design enable to respond to complexity by allowing to define flexible processes that can, from one side imitate the organicity of the natural systems and on the other include the iterativity typical of the scientific method; to this latter, the design adds the pragmatic aimed at finalizing modifications of the world (not only its understanding); therefore the design processes are not only problem-based, but also project and process based, i.e. P^3BL [30];

iii) methodological, for the ability to absorb the best of what is expressed by various disciplines and to integrate all within the processes mentioned above; consider, for example, the methodologies derived from cultural anthropology, that suitably readjusted, are used in the process of problem setting; those derived from cognitive science used in the design and implementation of the tests; those derived from engineering used in the medium- and high-fidelity rapid prototyping, etc. [31, 32];

iv) didactic, as demonstrated by the continuing tension in readapting the methods outlined above and in developing tools and procedures that allow their practical implementation in different contexts and situations, in other words by the effort to be at the same time general and flexible [33, 34];

We wish to emphasize that the recognition of the pedagogical centrality of Design automatically leads to the need to provide the new environments with tools able to favor the spread of a sufficient level of "design literacy". It is not by chance that the letter D of the DULP vision [10,11] remind us the relevance that the Design is going to assume as cornerstone of the XXI century's education, and that in Life we have started the development of co-design lab.

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Outcome-oriented Fitness Measurement of Personal Learning Environments

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ABSTRACT

Personal learning environments (PLEs) comprise a new kind of learning technology which aims at putting learners into centre stage, i.e. by empowering them to design and use environments for their learning needs and purposes. While a lot of research and development is going on in realizing and providing technical PLE solutions, less effort is spent in examining the 'fitness' of PLEs. By fitness we refer to the property of a PLE that it is successfully used to achieve a goal. In this paper we attempt to formalize the PLE fitness by focusing on one specific aspect, namely on outcomes of PLE-based activities. For this purpose, we analyze a certain kind of PLE outcomes, i.e. publications, by measuring their impact and use real-world data harvested in the Web to propose a mathematical fitness model. Furthermore, we address factors characterizing the fitness of a publication as well as preliminaries of our approach. The paper concludes with pointing out related findings from other fields and possible future work on outcome-oriented PLE fitness measurement.

Categories and Subject Descriptors

G.3 [**Mathematics of Computing**]: Probability and Statistics: *Distribution functions, Time series analysis*, H.2.8 [**Information Systems**]: Database Applications: *scientific databases*, G.1.2 [**Mathematics of Computing**]: Approximation: *Nonlinear approximation*.

General Terms

Algorithms, Measurement, Experimentation.

Keywords

Personal Learning Environments, Scientific Publications, Citation History Analysis, Fitness Function, Gamma Distribution.

1. INTRODUCTION

According to Henri et al. [1], personal learning environments (PLEs) refer to "*a set of learning tools, services, and artifacts gathered from various contexts to be used by the learners*". Furthermore Van Harmelen [2] states that PLEs aim at empowering learners to design (ICT-based) environments for their activities so that they can connect to learner networks in order to collaborate on shared outcomes and acquire necessary (professional and rich professional) competences. In the last years a lot of work has been investigated in the development and application of new, PLE-related technologies (like apps, widgets or gadgets) and their underlying infrastructures (widget containers, personalized websites, mobile phones etc).

Considering the spreading of these technologies in society and the raising profits of leading companies in this sector (e.g. Apple or Google), they are highly successful. However less attention is paid to their usage as personal learning environments and their (positive and negative!) effects on lifelong learning. In order to formalize and examine the evolvability of PLEs, we build upon the notion of fitness, a concept given by evolutionary theory. By comparing the development, spreading, and utilization of PLEs – the technical infrastructures as well as their entities, e.g. tools and their features – to genetic evolution [3], a learning environment can be understood as a socio-technical system (*organism*) with its functionalities (*traits*). According to our initial definition, a PLE is a set of tools, services, artifacts, and peer actors, thus the fitness of a PLE refers to specific situations in which it is used and consequently to defined purposes (*fit-for-purpose*) as well as to the scope of a community and a context (*local fitness*).

Over time, PLEs can evolve, for instance specialize, according to situations in which certain features are used more frequently and others are ignored or even removed – as learners also demand new features, developers are part of this evolutionary process and implement them so that a PLE solution is being used in the future. Such processes bear a resemblance to the concept of natural selection [4]. In the context of this paper, fitness refers to a property describing PLE functionalities. Fitter PLE features (*genes*) become more common, i.e. a certain form of a feature (*allele; DNA sequence*) is used more frequently, spreads faster, or can even substitute other forms of the same functionality.

We explain these definitions through two examples for the evolution of software artifacts in praxis. A first example comprises a new way of providing recommendations. In the last few years many web applications have included recommendations which appear on typing in a term into the search field. Restricting these recommendations to the user's context (e.g. Facebook.com) or auto-completing the query on the basis of terms given by many other users (e.g. Google.com) seem to be two manifestations of this feature which will become more important in the future. So, the generic function “recommendations” has been specialized over time. In a second example a new researcher enters a scientific community on statistical mathematics. In this group of researchers a specific tool, namely the R software, is favored for teaching and research activities. Thus the new member is facing a tool with a high fitness factor within the community and can either work with this tool or try to establish some other software in this community, consequently opposing the R framework.

Overall, the idea of our approach is to consider PLEs as the outcomes of (collaborative, ICT-based) learning – which is also stated e.g. by Wild et al. [5] – and to formalize and examine their evolution over several generations. Unfortunately this would require detailed data about PLE-based activities over a long period of time – which is not easy to get and which we do not have. Therefore we propose to focus on certain aspects of PLE activities, namely on PLE outcomes in the form of scientific papers. We use the information on publications to model and analyze their fitness with respect to their scientific impact.

The rest of the paper is structured as follows. The next section elaborates our approach towards outcome-oriented fitness measurement as well as preliminaries and related work. Then, section 3 describes the stepwise development of a fitness function for PLE outcomes and examines different characteristics of this model. Section 4 summarizes findings as well as similarities to other fields, and discusses the approach towards its relevance for the PLE fitness, before an outlook on future work is given.

2. CONCEPTUAL APPROACH, PRELIMINARIES, AND RELATED WORK

As mentioned before, we consider scientific papers as typical PLE outcomes and use bibliographic data to examine and formalize their fitness. In a first step we have to clarify how publications and PLEs are related. In former research we have elaborated the notion and the most important concepts of PLE-based learning ecologies [6]. Figure 1 shows what PLE-based collaboration looks like. Learners are involved into different activities in which they try to achieve personal and group goals (e.g. publishing a paper to a journal). They use various tools to collaborate on shared artifacts. In the context of this paper, publications can be seen as typical outcomes of such activities, as they are created by one or more scientists using different tools – and even single-authored papers normally involve other actors in the background.

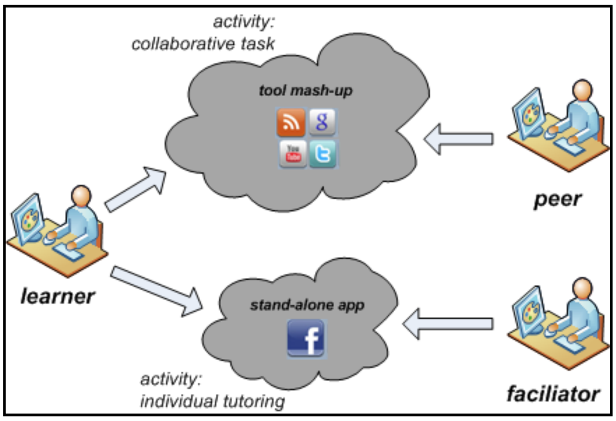

Figure 1. Example scenario for PLE-based collaboration.

On a theoretical level and putting the learner (actor) central stage, Klamma and Petrushyna [7] propose a model of learning ecologies which is based on the Actor-Network Theory (ANT) and describes five important entities of a PLE:

- **Processes:** *Activities* carried out for educational reasons, at workplace, or due to personal goals (e.g. a job task in a business process, attending a course for further education, or a spare time activity requiring the acquisition of new competences)
- **Media:** *Collection of learning resources* required for or created in these activities (e.g. the Wikipedia platform, learning objects repository, or simply the Internet)
- **Artifacts:** *Documents* and other (digital or real-world) artifacts collaboratively created and accessed by learners (e.g. Wiki articles or a joint paper)
- **Agents:** *Actors*, no matter if humans or software (e.g. peer learners or functionality provided by software)
- **Communities:** *People sharing the same environment*, e.g. in terms of having common interests, working on the same artifacts, being connected to the same actors (e.g. a group of learners trying to achieve a course goal or a special interest group for a specific topic)

In the scope of this paper, the PLE related to a publication can be described as follows. A scientific publication is an outcome of a PLE-based activity which involves several human agents in different roles (main author, co-authors, organizer/editor, reviewers, etc.) and using different tools (MS Word, email, conference/journal submission system, etc.). The whole publication process consists of various different activities, e.g. research, writing, and submission activities. Normally, a paper also addresses one or a few scientific communities which can be determined by the targeted journal or conference.

Realistically the PLE of a publication cannot be fully reconstructed any more, as the tools used and the interaction sequences were not tracked sufficiently. Thus, we examine the fitness (success) of papers towards their impact in scientific communities by analyzing the number of citations of different kind of publications over time. The analysis of citations and the citation history of papers is a well-explored field (cf. [8]). Furthermore shortcomings of citation analysis, like biased citing, secondary sources, variations in citation rates with disciplines or nationalities, and many more, are elaborated extensively [8, 9]. Yet, we consider these problems of citation analysis (similarly to the learning environment itself) as part of the outcome of PLE-based activities, being worth an in-depth analysis.

With respect to existing citation indices like CiteseerX (http://citeseerx.ist.psu.edu/), the ISI Web of Knowledge (http://www.isiwebofknowledge.com/), or the ACM Digital Library (http://portal.acm.org/), new tools such as Google Scholar (see http://scholar.google.com/) or community approaches like Mendeley (see http://www.mendeley.com/) provide new opportunities for citation analysis on the basis of large and topical data-sets (cf. upcoming section and [10]).

In the following we describe the development of an approach for formalizing the fitness (citation success) of papers and discuss characteristics of this fitness model.

3. MEASURING AND FORMALIZING THE FITNESS OF SCIENTIFIC PAPERS

First of all, we had to decide on the data source for the bibliographic data required for our approach. After inspecting possible platforms (CiteseerX, ISI Web of Knowledge, ACM Digital Library, Google Scholar, and Mendeley) we conducted a small evaluation study. Therefore, we selected four prominent (i.e. highly cited) publications for this brief evaluation, a well-known book on data mining and papers on booming topics in the Web (Semantic Web and the PageRank algorithm).

Table 1. Comparison of different citation indices (CiteseerX [CX], ISI Web of Knowledge [WoK], ACM Digital Library [ACM], Google Scholar [GS], and Mendeley [M]) on the basis of four highly cited papers and retrieved on February 8, 2011 (*) no. citations given by Scholar vs. sum of yearly citations, +) no. readers)

Publication on:	CX	WoK	ACM	GS*)	M+)
Data mining	n.a.	n.a.	n.a.	10700 /6035	61
Semantic Web	n.a.	1159	n.a.	10709 /8312	323
PageRank (1)	1301	n.a.	n.a.	3670/ 2949	44
PageRank (2)	2140	n.a.	1534	7245/ 5917	573

In Table 1 the comparison of different citation indices is shown. Overall, this statistic confirms the impressions of our inspection. For instance, the data quality of CiteseerX seems to be very poor, as it has no or faulty data on two of our selected publications. On the other hand, the ISI Web of Knowledge and the ACM Digital Library provides bibliographic data on a good quality level but the coverage seems to be poor. Mendeley is not a real citation index, as it rather contains usage data (no. readers) than citations. Yet, this data is interesting and valuable for our evaluation. In sum, we decided to use Google Scholar which contains significantly more and topical data-sets. Moreover, the quality of this data is on a reasonable level, which is also backed up by other evaluation studies, e.g. one on citation mining [11].

With respect to [12], citing a research paper follows the Poisson process, a stochastic process in which citations occur continuously and independently of each other. More precisely, the citation curve of a publication can be formalized by the convolution of two Poisson distributions, one describing the initial phase of a paper's uptake and another one representing its continuous aging process. As a simplification and to combine the two citation curves into one model, we propose to use the Gamma distribution to formalize the fitness of a paper according to its citations. The probability density function of a Gamma distribution is defined as follows [13]:

$$f(x;k,\theta) = \frac{x^{k-1} e^{-\frac{x}{\theta}}}{\theta^k (k-1)!} \; for\; k,\theta > 0 \; and \; x \geq 0$$

Different to former research which is based upon the Avramescu function [12] – a specialization of the Erlang distribution which itself is a special kind of Gamma distribution –, we use the Gamma distribution for formalizing the fitness of a paper, as it allows approximating the citation curve according to two parameters, the shape (k) and the scale (θ). Given the number of citations per year retrieved from Google Scholar, we use the citation history of prominent papers to develop a method for estimating these two parameters.

Figure 2 displays the citation curves of the four papers analyzed in Table 1. All of these publications are well cited and have sufficient data starting in the years 1998, 2001, and 2006. The book on data mining (green curve) is problematic, as it is the second edition and thus the citation history seems to be biased. However, the other three papers deal with important innovations in the field of computer science and are considered to be appropriate for developing a method for measuring the fitness of PLE outcomes.

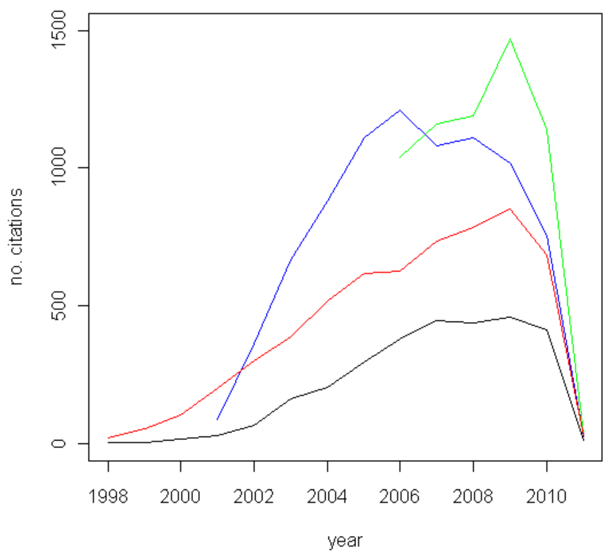

Figure 2. Citation curves of the four publications mentioned in Table 1 (data-sets taken from Google Scholar on February 8, 2011; green curve: data mining book, blue curve: Semantic Web paper, red and black curve: two papers on PageRank).

For developing our method to approximate the citation history according to a Gamma distribution, we used the second paper on PageRank (S. Brin and L. Page, "The anatomy of a large-scale hypertextual Web search engine", 1998) because sufficient data is provided over a long period of time (see red curve in Figure 2). Basically, our fitness measurement method consists of three steps to approximate a given citation history: (1) determination of the mode, i.e. the value that occurs most frequently in the data-set; (2) parameter estimation of the shape and the scale with respect to minimizing the error rate of the given sample according to the probability density function (pdf) of the Gamma distribution; (3) visualization and evaluation of the approximated fitness curve.

The first step, the identification of the mode, is the one which is the trickiest and highly restricts our approach but it is also necessary. As we have only data-sets of the first years after publications appear, we decided to select the mode manually due to two facts. On the one hand, distribution fitting algorithms are based on the preliminary that the values are distributed over time – which is not the case for our data. Existing software, like the open source framework for statistical computing and graphics (R Project, see http://cran.r-project.org/), provide packages for estimating the parameters of Gamma distributions (cf. [14]), but they do not lead to useful results for our data. On the other hand, we have to assume that the mode is already included within the data-set available, which is also a necessary condition for our approximation method.

However, having the mode of the distribution gives us the possibility to estimate the two parameters (shape k, scale θ) on the basis on the following mathematical relationship (setting first derivation of pdf to 0):

$$x_{mode} = (k-1)\,\theta \;\rightarrow\; \theta = \frac{x_{mode}}{k-1}$$

In a second step, we used (n-2) values of our citation history for estimating the two parameters so that the error rate is minimal. It is recommended to not use the citation data of the last two years (here 2010 and 2011) because of publication and indexing delays, thus the number of citations is incomplete. Given the mode, we have a written a R function which numerically calculates the best values for k and θ by means of minimizing the error rate of the first m values of the citation history (with m being number of values to the mode) according to the following equation:

$$mean\ error(k,\theta) = \frac{1}{m}\sum_{i=1}^{m}\left| x_i \frac{f_{k,\theta}(m)}{x_m} - f_{k,\theta}(i)\right| \rightarrow min.$$

After calculating the parameters (e.g. k = 5.042 and θ = 2.968827 for the selected PageRank paper), the third step comprises evaluation (the relative error for these parameters is 7.85%) and a visualization of the approximated curve. Figure 3 shows the number of citations gathered from Google Scholar and the approximation according to the Gamma distribution.

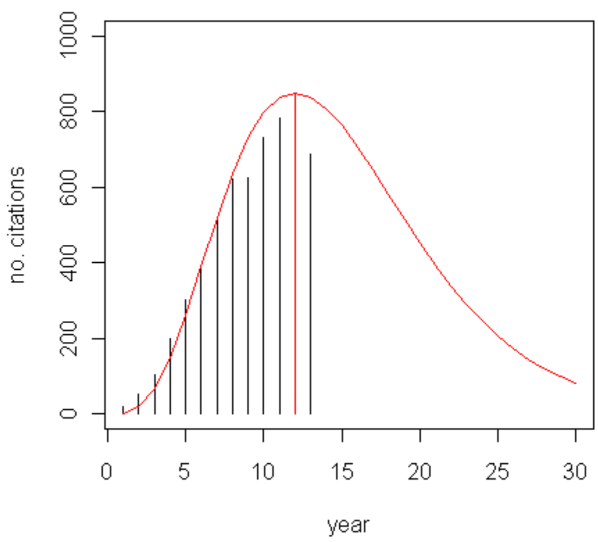

Figure 3. Gamma approximation for PageRank (2) paper from Figure 1 (x is the time axis starting with 1 as the publication year; red curve describes the Gamma pdf approximated according to the citation history).

In principle, we now can formalize the fitness of a PLE outcome by two numbers, the shape and the scale of the Gamma pdf. If based on sufficient data, this distribution of a publication's citation history seems to be reasonable, as it starts to have impact after being published, reaches a peak some years in the future and then decreases again. The last phase can be argued by effects like more successful follow-up publications or aging of published knowledge. Overall, this fitness measurement enables comparing the success (impact) of publications to each other.

In the next step we analyzed the fitness of different publications: (a) the most frequently cited papers, i.e.

fundamental literature of a selected scientific community, (b) a successful follow-up paper by a lead researcher, (c, d) average (less successful) papers of the same author (single-authored and co-authored papers), and (e) the mostly cited paper of other researchers in a selected field. We used the bibliographic data of the adaptive hypermedia (AH) community, as this discipline is very young and most of the key publications are captured by the index of Google Scholar.

Table 2. Comparison of selected papers according to our fitness estimation method (data retrieved from Google Scholar on February 23, 2011)

Publication:	k	θ	norm. factor	rel. error
1. Brusilovsky, “Methods and techniques of adaptive hypermedia”, 1996 [**1373 citations, 16 values**]	3.105	4.751	2336.03	12.54
2. Brusilovsky, “Adaptive hypermedia”, 2001 [**1274 citations, 11 values**]	2.993	3.010	2043.25	9.68
3. Brusilovsky et al., “From adaptive hypermedia to the adaptive web”, CACM, 2001 [**303 citations, 11 values**]	3.347	2.983	486.46	15.82
4. De Bra, Brusilovsky, “Adaptive hypermedia: from systems to framework”, 1999 [**159 citations, 13 values**]	3.724	2.937	275.57	15.60
5. Brusilovsky, “Adaptive educational systems on the world-wide-web”, 1998 [**174 citations, 14 values**]	6.648	1.062	141.29	24.92
6. De Bra et al., “AHAM: a Dexter-based reference model for adaptive hypermedia”, 1999 [**326 citations, 13 values**]	3.372	2.530	394.38	22.73

Table 2 gives an overview of the comparison of papers being relevant for the assumptions (a-e). A first observation deals with the relative error of the approximation. Obviously the error decreases if more values per year are given. Particularly the last two publications are approximated moderately, as the relative error is above 20%. Yet, the approximation according to Gamma distribution works well, as also shown by the papers’ fitness functions in Figure 4. As mentioned before, it is important to not consider the two latest years of the citation history retrieved due to publication and indexing delays. These values (2010, 2011) are also not visualized in the figure.

A second interesting observation concerns the shape parameter (k). A lower shape factor is an indicator for a fitter paper, i.e. a publication cited more often in a shorter period of time and reaching the citation peak earlier. Comparing the first two papers, both were published by the same author and on the same topic. Yet, the second one is cited nearly as much as the first one although being published 5 years later. Most probably, the second paper will outpace the first one in the next years, which can be concluded from the fitness functions shown in Figure 4. As we assume the fitness of a publication to be dependent on the community, we restrict the comparison of Gamma parameters to this scientific field. Thus, the shape calculated for the PageRank paper (Web researcher) cannot be set in direct relation with the shape factors of the AH papers.

Next to the speed of a paper’s uptake, success can be also determined by the number of citations in general. Here, both scaling factors, the Gamma parameter θ (second column of Table 2) as well as the factor to normalize the citation history to the pdf of the Gamma distribution (third column), allow inferences on the quantity of citations. The first two papers are cited significantly more often than the papers 3 and 6 which in turn are more successful than the publications 4 and 5. However, both scaling factors dependent on the shape k that is why the fitness function of the first paper has a higher scale and a higher normalization factor but a lower peak.

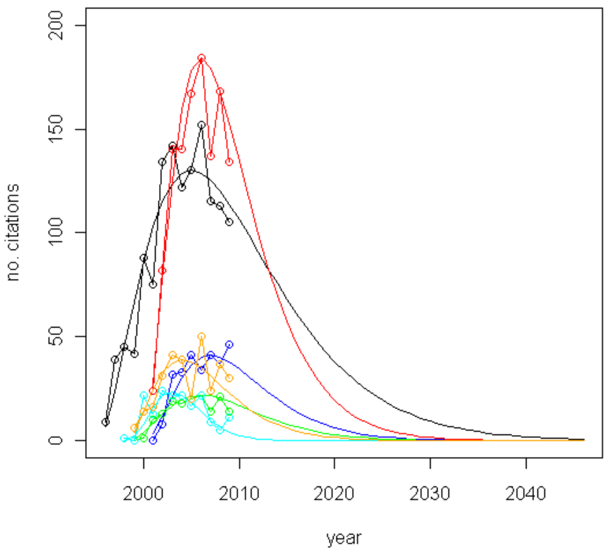

Figure 4. Fitness functions and citation histories (from the publication years to 2009) of the papers depicted in Table 2 (colors: 1. black, 2. red, 3. blue, 4. green, 5. cyan, 6. orange).

Overall, we have tackled a set of very diverse publications for which the fitness functions are visualized in Figure 4. The first two papers (scenario (a); black and red curve) are the most frequently cited papers of one of the lead researchers of the AH community. These two curves evidence that two very successful papers behave different in being cited within a community, i.e. that one publication can be fitter than another one and that preferential attachment [15] – a favored paradigm for emergent, networked structures – is not always valid.

The fitness of the third paper, a successful follow-up paper of the AH lead researcher (scenario c), is similar to the mostly cited paper of another (well-known) researcher in this scientific field (scenario e). The less successful papers (scenario d) are problematic as the approximation of the fitness curve does not work that good (high relative error). Most obviously, they are characterized by a shape which is growing slower. Particularly paper 5 has a shape of over 6, meaning that the data could be faulty or that the uptake of this work was that slow.

Addressing further issues that might have an influence on our fitness estimation method, [8, 9] give a comprehensive overview on problematic issues of citation analysis. Due to a lack of space and time, we have not addressed the phenomena of self-citations which we assume to be necessary to successfully 'initialize' the fitness of a paper. Concerning such influential factors, we refer to future work which could aim at differentiating between self-citations and citations by other researchers and examining the different fitness functions.

Finally it has to be outlined that our fitness estimation method also includes a model for predicting the future citation frequency. Given the data of the papers we have examined, this prediction worked fine for those citation histories going beyond the citation peak. On the other hand, this prediction is also based on the assumption that in the future no unforeseeable event concerning a publication (e.g. a rediscovery after a couple of decades) occurs. Here, our approach is restricted to the condition that the citation peak is given and that it is a global maximum.

4. CONCLUSIONS, RELATIONS TO OTHER FIELDS, AND FUTURE WORK

In this paper we have examined a very particular aspect of personal learning environments, namely publications as outcomes of distributed, collaborative, and technology-based activities. Precisely we have proposed a method for formalizing the fitness of such scientific content artifacts, i.e. the success in being taken up, on the basis of usage data (the number of citations) retrieved by a large and up-to-date citation index. Although being restricted by some hard conditions (sufficient data available; citation peak given and global maximum; dependency on a scientific community), the fitness measurement method seems to be valid and reasonable due to the following reasons.

On the one hand, approximation works fine for well-cited papers, as shown in the last section. On the other hand, citing scientific publications is a natural process for which the waiting times between Poisson distributed events are relevant [16], which can be characterized by a Gamma distribution. Similar processes can be observed in other areas, like weather forecast (estimating the likelihood of monthly rainfalls for draught monitoring [17]), insurance businesses (effect of risk factors, like rainfalls, on insurance claims [18]), medical treatment (time to treatment response in arthritis patients [19]), or modeling the distribution of fitness effects in evolutionary biology in general [20, 21, 22].

Although the connection between scientific publications and the PLEs leading to such artifacts is very vague, we think that the fitness model proposed in this paper is generally relevant for PLE-based activities, as other aspects of personal learning processes (e.g. tool usage or communication behavior) might underlie a similar lifecycle and a curve following a Gamma distribution. In particular the results of our research are relevant for those activities which aim at creating artifacts that should be extensively used by others. By applying our approximation method it is possible to compare the success of papers with each other and to predict their future performance. However, we see the work tackled in this paper as a first step only. Based on the fitness estimation method developed, next steps could address the fitness curves of publications according to different scientific communities (local fitness assumption), to the social networks of paper authors (co-author assumption), to self-citations (initialization assumption), to the novelty and quality of publications (fit-for-purpose assumption), or to other characteristics of such PLE outcomes.

Furthermore, future work could comprise a closer examination of the PLEs which led to high impact papers, i.e. by interviewing the authors of such publications. Additionally it would be valuable to develop a tool for (semi-)automatically calculating the fitness curve of user-selected papers. From the evaluation perspective it is necessary to examine papers of different scientific fields – if sufficient data is available – and to use data from other systems, i.e. real usage data on publications as captured e.g. by Mendeley (cf. author readership analysis available at http://readermeter.org).

5. ACKNOWLEDGMENTS

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Interoperability Requirements for a Sustainable Component to Support Management and Sharing of Digital Resources

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ABSTRACT

Platforms such as YouTube, Flickr or Delicious that allow users to manage and share different kinds of digital resources belong to the most popular applications in what is usually subsumed under the umbrella term *Web 2.0*. In the context of PLEs, the ability to manage and share digital resources used within a learning process is also one of the most important features. This paper gives a coarse overview of key aspects to consider when aiming to provide a sustainable, adaptable component for resource management and sharing that can be integrated into different, heterogeneous digital environments. The ALOE (http://aloe-project.de) system will be presented as an example for the realisation of a respective component meeting the presented demands.

Keywords:

Resource sharing, Metadata, Interoperability, Social media

1. INTRODUCTION

The ability to support management and sharing of digital resources is a key feature in any PLE. A variety of tools and platforms exist that support such features for different kinds of contents (e.g., music, video, photos) and application scenarios. Yet, most of them only offer few possibilities to integrate with other tools, and each of the platforms usually has to be accessed separately in order to add, annotate, manage and search for contents. Social bookmarking systems such as Delicious[1] or Diigo[2] are a means to annotate and store information about resources from different sources. However, the vast majority of these systems only provides very basic means to organise own contributions and is neither instantiable, nor can be adapted to the specific needs of a scenario. Consequently, it is doubtful that future and not yet anticipatable scenarios can be supported by means of these tools.

What is needed in order to ensure sustainability is a comprehensive approach and framework that allows contributing, managing, and sharing arbitrary digital resources, that allows to exchange information with components in potentially any kind of digital environment, and that allows to adapt to the specifics of different scenarios.

In the following, we will first provide a coarse overview of interoperability requirements that have to be met when aiming at such a sustainable approach for resource management and sharing. The ALOE system will then be presented as an example for the realisation of a respective approach meeting these demands.

2. INTEROPERABILITY REQUIREMENTS

The IEEE[3] defines interoperability as follows [3]:

Interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged.

For the design of an application to manage and share digital resources, this has to be considered for

- the selection of supported application scenarios,
- the resource types to be supported,
- the metadata to be used, and
- the interfaces offered to users and other systems.

In the following, we will briefly discuss each of these aspects.

2.1 Supported Application Scenarios

As a first step in the design process, one has to decide for which scenarios support should be provided. Concentrating on a very specific scenario (e.g., "knowledge workers in a research department") in the system's design can provide the benefit of a customised solution that takes into account the very specific characteristics of this scenario and the needs of the involved users. Yet, such a very targeted approach inevitably has several downsides:

- A huge modelling effort is required, e.g., for specifying and generating complex and tailored structures such as ontologies.

[1] see http://delicious.com
[2] see http://www.diigo.com
[3] see http://www.ieee.org

- A created model can always only be a snapshot – yet, people and organisations evolve. Thus, maintenance is required, which is usually a very complex and time-consuming task. Furthermore, no model is able to anticipate all possible needs and scenarios.
- The restriction to a very specific scenario and model hinders interoperability with other components (e.g., tools, technologies, and other data sources) that might be used in such a scenario. Although the adaptation of such components is sometimes possible, this is once again a usually complex and time-consuming task.

Instead of focusing on specific scenarios and defining prerequisites that have to be met for infrastructures, domains or user types, a sustainable component should follow a generic approach that can potentially be applied to support access to digital resources wherever this support is needed.

2.2 Resources

As any kind of resource can be part of a learning process, it should be possible to incorporate any type of digital resource. This includes arbitrary types of multimedia resources (e.g., HTML, PDF, MPEG), but also services or even physical resources just represented by a URI in an information system. "Incorporate" here means:

- When a digital resource is newly created or not yet accessible in the respective environment, it should be possible to contribute this digital resource, and to make it accessible. A system that offers this realises a *repository*.
- For digital resources that are already accessible in the respective environment, it should be possible to integrate them into the system without having to physically copy them. Otherwise, the following problems are very likely to arise:

  Maintenance issues: When digital resources are copied from a source where new contents are added, or existing contents are deleted and modified, the system will have to react to these changes. This is usually an expensive and time-consuming task.

  Memory requirements: Every digital resource that is copied will require some memory capacity. For large collections or certain resource types such as videos, this can result in very high memory requirements.

  Legal concerns: Sometimes it is simply forbidden to physically copy existing digital resources and to provide them in a different system.

  A system that offers this realises a *referatory*.

2.3 Metadata

Before discussing interoperability aspects for metadata elements and representation formats, we will first briefly elaborate on the need to take into account subjectivity and diversity.

Subjectivity and Diversity

We always have to consider that metadata is created for certain purposes in certain contexts, and that it is impossible to anticipate for whom and for what reasons a resource might be considered as relevant in the future. We have to accept and to embrace the fact that there is no "single and correct" way to describe a resource. As a consequence, we should allow *subjectivity*, and also *diversity* in the metadata about resources, instead of a metadata monoculture[4]. The need to support diversity is also motivated by the fact that we aim to support the access to digital resources in a variety of application scenarios, especially with heterogeneous components and most likely also heterogeneous metadata formats used for resources. These requirements are also supported by Nilsson et al. in [6], where the authors identified the needs for Semantic Web architecture, concluding that it should be:

- Evolving, supporting a dynamic metadata eco-system
- Extensible, allowing introduction of new vocabulary with new semantics
- Distributed, supporting descriptions by anyone about anything, anywhere
- Flexible, supporting unforeseen uses of resources
- Conceptual, supporting the evolution of human knowledge

It is clear that a one-size-fits-all solution for metadata about resources will not fit these needs. Instead, an ideal infrastructure would be generic in a way that allows for the generation of adequate resource descriptions for different users in different scenarios. Therefore, potentially any existing metadata might be incorporated. Different approaches to generate metadata can only be applied successfully in certain scenarios and for certain types of digital resources and metadata, and each of them has its benefits and limitations. Ideally, a digital environment should allow in each scenario to combine the benefits of each of the metadata generation approaches and to avoid the limitations. To allow for subjectivity and diversity, human generated metadata is most important, as only humans can contribute with different views and opinions. The need for diversity demands a non-authoritarian approach, supporting different views of the same resource. Thus, social metadata (i.e., metadata generated in social media environments) is most likely to meet these requirements, because it allows any user to contribute metadata about a resource.

As a consequence, we should be able to make use of potentially any metadata existing in the environment where our component is introduced. Moreover, it should be possible to contribute a variety of different metadata for digital resources. Such metadata can immediately be helpful for end users (e.g., bibliographic information about a resource), and it can also be an important source

[4] The term "metadata monoculture" was coined by Randy Goebel in 2008

for several functionalities (e.g., search or recommendations).

Metadata Interoperability

Concerning metadata elements and representation formats, drawing upon standards is required. Duval et al. provided the following fundamental principles for interoperability [2] that where enhanced by Nilsson et al. [5] who added the principle "Machine-processability".

- *Extensibility:* The ability to create structural additions to a metadata standard for specific needs of a domain, community or application
- *Modularity:* The ability to combine different, heterogeneous metadata fragments
- *Refinements:* The ability to create more fine-grained descriptions compatible with more coarse-grained metadata, and to translate a fine-grained into a more coarse-grained description
- *Multilingualism:* The ability to express, process, and display metadata in a number of different linguistic and cultural circumstances
- *Machine-processability:* The ability to automate processing of different aspects of the metadata specifications (e.g., to handle extensions, or understand refinements

2.4 Interfaces

Our component will of course have to provide interaction means for other systems as well as users. The way this is realised also has a significant impact on the desired interoperability.

Access by Systems

In order to allow the usage of an approach in as many scenarios as possible, and to foster the adoption of as many users as possible, the following aims should be followed:

- *Low technical barriers for system usage:* Users should be able to use functionalities with minimal efforts. This means as few restrictions as possible concerning the technical environments in which the hub can be used, as well as minimal installation efforts.
- *Low conceptional barriers for system usage:* Conceptional prerequisites for system usage such as the use of certain metadata formats should be kept to a minimum, while still allowing to provide added value for as many scenarios as possible.

As we want to enable the integration in existing environments with different systems and components, we need more than "just" an adequate user interface. Interfaces allowing an easy creation of mash-ups and complex functionalities using information from our component are required. Thus, interoperability is a very important aspect, and we should offer access to potentially any data and functionalities, regarding privacy aspects at the same time.

User Interfaces

Of course we need to provide interaction possibilities in an adequate way so that users are encouraged to make use of them. It is thus important to provide a user interface following principles such as simplicity [4] and joy-of-use [7]. Furthermore, mechanisms that attract and motivate users (e.g., by using reward mechanisms or game-based approaches) can be offered.

In order to allow decentralised contributions of digital resources and metadata in a way that fosters interoperability, users should be offered the possibility to use functionalities of our component in their usual contexts and applications. This can of course be realised if the persons in charge integrate functionalities into the respective applications. A more lightweight approach that allows integrating information or functionalities including user interfaces is to use *widgets*[5]. A widget is an element of a graphical user interface providing information and/or interaction possibilities [8], and that can be embedded into existing environments (e.g., a lot of widgets exist that can be embedded in HTML pages).

Furthermore, as we aim at a generic approach that can be used in a variety of scenarios, the user interfaces should be adaptable in a way that allows to address specific needs of a scenario (e.g., concerning a corporate identity or a certain terminology).

3. THE ALOE SYSTEM

The ALOE is a web-based social resource sharing platform developed at the Knowledge Management group of DFKI. It allows contributing, managing and sharing arbitrary types of digital resources such as text documents, music, or video files. Users are able to either upload resources (using the system as a repository) or by referencing a URL (using the system as a referatory). Users can tag, rate, and comment on resources, they can maintain resource portfolios, join and initiate groups, etc. Furthermore, arbitrary additional metadata can be associated with resources. Further system features are, among others:

- Group management for open/closed/invisible groups.
- Publish as private, public, or only for a certain group.
- Find resources with different types of search filters (title, description, tags, ...).
- Rank search results according to different criteria (most viewed, best rated, most recent, most bookmarked...).
- Advanced search with different filter criteria (filter by mime type, filter by license, filter by date, ...)
- Feed support (Atom) and email reports for different topics (e.g., activities in groups, activities on resources).

[5] The term *widget* is an abbreviation of *window gadget*

- Automatic metadata generation based on the Aperture[6] framework.
- Embedded player for various resource types (e.g., flash, mp3).
- Thumbnail generation for all common multimedia formats.
- Optional parallel uploads or status updated in other platforms (e.g., Delicious, Diigo, and Twitter).
- Export of own resources, search results and group resources as Netscape Bookmark File (importable in all common browser and bookmarking platforms).
- Functionalities are also offered as services (SOAP/REST API). This allows for an easy integration in other contexts and (existing) components.
- Easy adaptation of design, menus and texts for new scenarios.
- Arbitrary metadata can be integrated into the system and associated with resources thus, the integration of existing data is easy to realise.

3.1 System Design

To allow the usage of ALOE in as many scenarios as possible, and to foster the adoption of as many users as possible, ALOE was designed as a server-based application where information is exchanged via HTTP. On the one hand, the system's functionalities are offered via a graphical user interface that can be accessed with any common web browser that can connect to the ALOE server. On the other hand, a Web Service API is offered that allows accessing the ALOE functionalities. For these purposes, SOAP was chosen as a standard and platform-independent, XML-based protocol.

To foster interoperability, ALOE uses several standards for content representation and delivery:

- SOAP (Document/Literal) is used to pull/push data from the MACE frontend.
- An OAI target allows the harvesting of social metadata.
- A CAM service for usage metadata is provided.
- ALOE metadata uses DC elements wherever possible (dc:contributor, dc:date and dc:format (all created automatically when contributing a resource), dc:creator, dc:description, dc:rights and dc:title).

ALOE can be used as a stand-alone component, but also realises a social backbone that allows introducing social media paradigms in existing (heterogeneous) infrastructures. The system comprises the following components:

- *AloeFeeds and AloeInfoMail:* To create feeds and email reports about a variety of system activities, these components directly access the ALOE database as shown in Figure 1.
- *AloeMultimediaServlet:* The AloeMultimediaServlet is responsible for the provision of all resources stored in the ALOE database (e.g., buddy icons or file resources that were uploaded).
- *AloeThumbnailer:* This component is requested when preview images of uploaded files shall be generated.
- *AloeView:* The AloeView realises the Web Interface as already presented.
- *AloeWebService:* This is the main component of ALOE that offers access to a variety of more than 150 methods to access, contribute, and manipulate user data, resources, collections, and groups.
- *ApertureWebService:* This service uses the Aperture framework to extract metadata about resources. It can be used, e.g., to provide recommendations when resources are contributed.

3.2 Sample Use Cases

ALOE was developed in a way that allows to access its functionalities in arbitrary contexts and environments. Furthermore, the AloeView can easily be adapted to the needs of a specific scenario. Consequently, several instances of ALOE are used in different scenarios and projects, among others:

- *ALOE-public*[7] is an ALOE instance that is publicly available since 2008. It is used in several real-world scenarios (e.g., by the Institut Henri Tudor in Luxemburg), but also as a simple playground.
- *Mindpool* is DFKI's internal social media suite for all DFKI employees (in Berlin, Bremen, Kaiserslautern and Saarbrücken). Mindpool consists of two components: mindpool hints is a microblogging tool based on the Open Source microblogging service status.net, and mindpool treasures is a social resource sharing platform based on ALOE.
- *MACE:* The objective of the European Project MACE[8] (Metadata for Architectural Contents in Europe) is to create a common infrastructure for enriching and retrieving educational contents about architecture in Europe. It was co-funded by the EU eContentPlus program from 09/2006 until 10/2009. All community features in MACE are realised using ALOE as a social backbone.
- *C-LINK:* The aim of C-LINK (Conference Link) was the development of a web based tool to support conference attendees. With C-LINK, users can share papers and presentations, generate individual conference schedules, get personalized recommendations to find interesting events and attendees, etc. C-LINK is based on ALOE and was used during the KI 2008 (the Annual German Conference on Artificial Intelligence) in Kaiserslautern and the ICDAR 2009 (the

[6] see http://aperture.sourceforge.net

[7] see http://aloe-project.de/AloeView

[8] see http://www.mace-project.eu

International Conference on Document Analysis and Recognition) in Barcelona.

- *RADAR:* The aim of the project RADAR[9] (Resource Annotation and Delivery for Mobile Augmented Reality Services) is the development of an ALOE-based infrastructure to contribute, organize and annotate multimedia resources that can be used within mobile augmented reality services. Besides adapters for existing services like Layar or Wikitude, a new personalized and location-based mobile augmented reality service will also be developed.

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[9] see http://radar-project.de

The Four Elements of a viable PLE

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ABSTRACT
In this paper, we propose and discuss four fitness features considered as essential for developing personal learning environments (PLE) that are viable and ready for appropriation.

Categories and Subject Descriptors
K. **[Computing Milieux]**: K.3. Computer and Education, K.4 Computers and Society- *miscenallenous*.

General Terms
Design, Human Factors

Keywords
Personal Learning Environments, lifelong learning, knowledge management, social media

1. INTRODUCTION
Rather than being confined to earlier life stages and strictly acquired within standard educational systems, learning should be *actively* pursued during the lifetime period. "Lifelong, lifewide, voluntary, and self-motivated" learning [1] refers to the activities that people conduct during their lifetime, to develop knowledge and competences, motivated by personal, social as well as employment reasons [2,3]. Lifelong learning is about learning anything, anywhere, anytime and anyway. It encompasses formal, non-formal and informal learning. Formal learning refers to intentional learning that occurs in structured contexts, and often leads to a formal recognition (e.g. diploma, certificate). Non-formal and informal learning, on the other hand, take place in environments that are neither essentially learning-oriented, nor structured in terms of learning objectives, material, time, or support [4]. Different from non-formal learning, informal learning is accidental or spontaneous, and occurs over the lifetime period [5,6].

Traditional LMS (Learning Management Systems) are not suitable for lifelong learning. LMS systems are usually characterized by a hardcoded asymmetry in user rights [7]. Students usually have single predetermined roles, share the same homogenous learning context, and are expected to achieve the same learning goals within the same period. Moreover, learning content is pre-packaged in learning units, has a restricted visibility scope (usually limited to the course duration), and is isolated from the outside world. Sometimes, courses cannot even be shared within the same LMS.

To better address the requirements of lifelong learning, educational systems need to become part of an external system accounting for learning inside and outside formal academic environments [8]. There is a need to shift from traditional LMS *applications* particularly focused on formal interactions and learning, to online personal learning *environments* (PLE) supporting both institutional and self-directed, intended and accidental learning. Successfully sustaining lifelong learning with online PLE requires developing and adopting new design patterns, models, and prototypes that can substitute for prevalent LMS design patterns [9]. In this paper, we discuss four elements deemed important for ensuring an online PLE's fitness for adoption and lifelong survival.

2. THE FOUR PLE ELEMENTS
This paper is based on the following definition of online PLEs: online PLEs are environments that are built from the perspective of the *individual* rather than the *institution* [10] and give learners the opportunity to decide their own learning goals, control their learning spaces [11] and interact with each other during the learning process [12]. The four identified features for building successful PLE are described below.

2.1 Encouraging active participation by adopting social media paradigms
The problem of low participation and lack of personal incentives was a major issue in early collaborative applications [13]. By adopting a user-centered bottom-up philosophy and relying on Web 2.0 technologies, social media applications have successfully overcome several problems identified by earlier CSCW studies, achieving by that a higher acceptability and a better user experience than traditional groupware. Online PLE should embrace the social media practices of knowledge "democratization" encouraging active participation and facilitating information dissemination as well as social interactions.

First, having low learning curves and offering interactive user-friendly interfaces is crucial for achieving fitness. With respect to developing interactive interfaces and improving the user experience, Web 2.0 technologies such as AJAX[1] play a particularly important role if applied properly [14].

Second, PLE should encourage learner-generated content by providing easy individual and collaborative authoring features such as blogs and wikis. Learner-generated metadata can be achieved by offering social tagging. The term folksonomy denotes the Web 2.0 way of organizing content using tags created and shared by people [15].

Third, PLE should combine content management facilities with social networking features allowing people to explicitly build and publish their own network of connections. People achieve lifelong learning by creating, maintaining, extending and strengthening their personal network composed of people with similar interest, groups, systems and specialized information sets [16].

Fourth, PLE should incorporate SALT features. SALT (Share, Assess, Link, Tag) is an acronym introduced in [17] to account for social media features that facilitate information dissemination and trigger interactions and reflection on knowledge artefacts. Assessment includes liking/disliking, commenting, and rating. Giving users the opportunity to easily contribute and express their views leads to a better appropriation of the online platform and increases their motivation to collaborate with others. Creating links (or bookmarks) to people and content and sharing them allows discovering the connections between different items, and discovering new items through their connections with known ones. Tagging can be used for describing an item or categorizing it using a user-defined label. Additionally, using tag-based search and tag clouds, learners can discover communities, activities, and artefacts that are relevant to specific topics of interest. Tagging people have also proven to be useful in formal contexts [18]. Influenced by users' tagging practices in collaborative tagging systems, tag semantics can emerge and evolve [19]. This helps communities to incrementally build a common vocabulary and externalize their shared memory. A direct advantage of incorporating these social media features is generating unobtrusive relation-based recommendations whereby metadata resulting from *SALT* actions are exploited in order to bring to the surface relevant people, activities, and knowledge artefacts based on how and by whom they have been *"salted"*.

2.2 Representing interaction and learning contexts in a flexible way

Ackerman identifies the necessity of providing flexible, nuanced and contextualized CSCW (Computer-Supported Collaborative Work) apparatus just as human behavior is "flexible, nuanced and contextualized" [20]. This statement perfectly applies to PLE that should be designed in a flexible and bottom-up way and account for **heterogeneous interaction and learning contexts**, including work, formal learning, and even play [21].

Learners should be given the opportunity to design and manage their own learning "**contexts**" by mashing up application widgets and useful artefacts, then sharing them with different people in different contexts. At the same time, it should not be imposed on learners to explicitly specify their interaction and learning contexts. PLE should allow different ways of context identification, ranging from those explicitly delimited by learners to those implied from their personal and collaborative actions. On the one hand, a community space constitutes an **explicit** context for potential interactions and learning revolving around the community's practices and involving its members, its shared artefacts, as well as its eventual sub-activity spaces. On the other hand, two or more actors commenting the same asset could also form an implicit interaction context involving them, the asset in question, its owner, and other contributors. Identifying interaction and learning contexts is crucial in PLE and is indeed more challenging than in traditional LMS. This is mainly because PLE are not confined to preplanned collaborative scenarios occurring within rigid and closed collaboration spaces. Instead, it also accounts for smoother forms of interactions that can **evolve** over time and induce both intended and unintended learning situations.

2.3 Offering elastic community and content management services

Communities of practice (CoPs) are defined as a group of individuals who choose to collaborate on a regular basis in order to learn and improve their practices related to a shared passion or topic of interest [22]. CoPs are considered to play a key role in fostering knowledge sharing and learning [23]. This triggers the motivation to sustain the initiation and evolution of CoPs in professional and educational environments [24]. When it comes to groupware systems, **flexibility** is a critical usability factor and their design should take into account the possibility for groups to evolve over time in terms of behavior, nature, and composition [25]. The same should apply for the support of community building and evolution in a PLE. Users enter their PLE as individual actors and not as pre-labeled members of a rigid organizational or institutional structure. Then, they can create their self-organized **communities** [26] or deliberately join existing ones, some of which may correspond to institutions and organizations. With respect to rights managements, there ought to be no pre-assumed hierarchy or default distribution of rights; a person can be a learner in one community and a moderator in another.

With respect to **content management,** learners should be able to create, share, modify, annotate, review and most importantly *repurpose* learning artefacts ranging from books to Weblogs, videos, podcasts and discussion archives [27]. Bringing together heterogeneous information sources requires adopting lightweight specifications such as RSS (Real Simple Syndication or Rich Site Summary) [28] and creative commons[2] licenses rather than strictly adhering to educational standards (i.e. IMS[3], SCORM[4]). Unlike traditional LMS where knowledge objects are organized within learning units and their usage anticipated, in a PLE, artefacts can exist outside the scope of activity spaces; they can be shared directly among actors without having to belong to an activity space or fall under the

[1]AJAX (Asynchronous JavaScript and XML) combined technologies exchange data asynchronously with the server to respond to a user's request. This avoids freezing the current

[2] http://creativecommons.org

[3] http://www.imsglobal.org

[4]http://en.wikipedia.org/wiki/Sharable_Content_Object_Reference_Model

umbrella of reaching an explicitly stated objective. Indeed, they can at any time be posted in one or more activity spaces, grouped together in a bottom-up way using tags, or explicitly related to other artefacts. This approach increases the learning flexibility and encourages the *spontaneous appropriation* of knowledge artefacts.

2.4 Providing personalized and contextual recommendation services

PLE can be classified as "open corpus" environments [29]. In a PLE, relationships between knowledge artefacts are not necessarily known beforehand, as it is the case in traditional hypermedia systems; instead, they can emerge, evolve, and expand during run time. In addition, in online platforms where everyone is a "consumer" and a "producer", contributions differ in quality, style, subject matter, target audience, composition, and reliability. In such open environments, personalized and contextualized recommendations can drive learners' attention to potentially interesting resources depending on their implicit or explicit interests, therefore avoiding information overload, and triggering formal and informal learning opportunities [30,31]. As mentioned earlier, PLE-embedded recommender systems can exploit SALT actions performed by users on knowledge artefacts and in different contexts in order to unobtrusively leverage user interest [32].

3. CONCLUSION

This paper discussed four main factors deemed crucial for developing PLE that are fit, ready for appropriation, and capable of evolving over time: the adoption of social media paradigms, the flexible representation of interaction and learning contexts (including those explicitly defined by learners and those implied from their actions), the incorporation of elastic community and content management features encouraging the spontaneous appropriation of knowledge objects, and finally the delivery of personalized and contextualized recommendation services. We are currently working on Graaasp[5], an online PLE that builds on the four PLE elements discussed in this paper.

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Visualizing PLE Usage

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ABSTRACT

In recent years, several researchers have been developing methodologies, technologies and systems to support the assembly of learning services, tools and resources in personal learning environments (PLEs). The overall goal is to enrich or even replace traditional learning management systems like Moodle and Blackboard with mash-ups of widgets and services that can be combined and configured in a flexible way, according to the specific needs of the user. In this paper, we describe our approach to visualize user interactions with widgets and services within such personal learning environments. These visualizations enable the exploration of learner behavior within PLEs. The major objective is to improve and evolve PLE related research and development according to feedback mechanisms based on empirical observation. In this paper, we present an overview of our method to capture usage behavior and a first prototype of a visualization dashboard that enables the analysis and interpretation of these data as a basis for evaluation.

Categories and Subject Descriptors

H3.4 (Web View/Social Networking/Web 2.0)

General Terms

Measurement, Design, Standardization

Keywords

Visualization, Analytics, Dashboard, Standardization, Contextualized Attention Metadata, Personal Learning Environments

1. INTRODUCTION

The development and proliferation of Web 2.0 technologies has impacted the way users interact with information and with each other. Web-based communities, wikis, blogs and social networks have experienced an exponential growth of both users and content, leading to potentially viral social networking, collaboration, communication and resource sharing opportunities.

The abundance of these technologies and services creates many new opportunities in various areas. One of those areas is Technology Enhanced Learning (TEL) that aims to bring together new technological developments and learning models to support learning processes. The ROLE project [3] is researching methods and technologies to enable learners to construct their own personal learning environments (PLEs). The overall goal is to create a flexible and open environment for the federation and mash-up of learning services according to the needs of the learner.

Whereas first prototypes have been elaborated in a successful way [5], the measurement of success of PLEs and the components that they aggregate needs further development and elaboration [4]. Within the scope of PLEs, different widgets and services are deployed that are implemented by different developers and, potentially, for different purposes. To measure success of these widgets and services within different contexts, the capturing and analysis of usage data is a key requirement. Such data is usually difficult to collect and analyze, because of the different ways log data are generated within different tools.

In this paper, we present a schema to generate usage data within widgets and services in a uniform way. Then, we present our dashboard that enables the visualization of usage data as a basis to detect changes in usage patterns. The purpose is to detect variations in the use of PLEs based on changes in usage patterns with widgets and services. The dashboard also provides insights into whether other similar widgets and services are also affected.

The Latour's actor-network theory (ANT) [9] suggests that understanding how human and the non-human entities interact with each other is the basis of the evolution. Based on Ben Shneiderman's Visualization Information Seeking Mantra [6] ("Overview first, zoom and filter, then details-on-demand"), we enable users to dig deeper into the data by filtering and interlinking different visualizations of usage patterns. These visualizations provide a basis for gaining insights into the uptake and usage of PLEs and the widgets and services that they aggregate. In addition, they can be used to detect evolution patterns in the use of widgets and services and their composition in PLEs.

The paper is organized as follows: in the next section, we present a schema for representing usage data in a uniform way. Section 3 presents the objectives of analyzing these data to detect changes in usage patterns and evolutions in PLEs. Implementation details of the visualizations and the back-end infrastructure to store usage data are presented in Section 4. A use case is presented in Section 5. Conclusions and future work are described in Section 6.

2. USAGE DATA

This paper focuses on visualizing usage data to enable awareness of user activities in a PLE and the evolution of widget usage.

PLEs have high evolvable characteristics [10] such as modularity, retargetable mechanisms or robustness to environmental and context change. Widget containers allow users to mash up their own learning environment in a flexible way. This enables the system to evolve and adapt to the new needs or requirements of the users.

ANT describes entities in 'actor-networks', defined as networks of identifiable actors, mediators and intermediaries, linked together by communication channels where the non-human entities, e.g. the software, participate in the evolution process [11].

In our case the widgets are the entities and the communication channel that they use to interact among each other is Open Social [13]. This communication is tracked with Contextualized Attention Metadata (CAM) [1]. By visualizing the tracked data we aim to provide useful information about the role that widgets play in the PLEs evolution.

CAM was developed to enable the capturing of usage data from a variety of applications, such as widgets and services that are aggregated in PLEs. CAM captures all kinds of user actions and can capture information about:

- the user
- the application used
- the action type (i.e. read, write, save, print, etc.)
- the resource on which the action occurred
- additional contextual information that may be available, such as time, location of the user, operating system or information related to the session or the IP address

CAM, which will be standardized by the CEN WS-LT working group on social data [14], enables structuring usage data in applications in a uniform way. In this way, attention tools can interpret information generated by different systems and use such information for various purposes, as we illustrate in the remainder of this paper.

3. ANALYSIS OF CAM DATA

CAM data can be analyzed to provide an overview about:

- *Where* (i.e. in which tools) did the action take place? This enables discovery of popularity, usage bursts and trends of tools. It can also uncover patterns like applications becoming unpopular, rising stars and new applications taking over older applications.
- *When* are the actions generated? This information is for instance useful in controlled environments such as formal learning environments where activities are usually scheduled. It is also quite useful in less controlled or more blended environments, to understand when learners are actually active.
- *What* happens in the environment? The dashboard makes it possible to zoom in on specific action types and resource types, so that we can study in detail what users are doing with resources.

4. IMPLEMENTATION

We have implemented a tool to visualize CAM data. The architecture of this tool is composed of three main components (Figure 1):

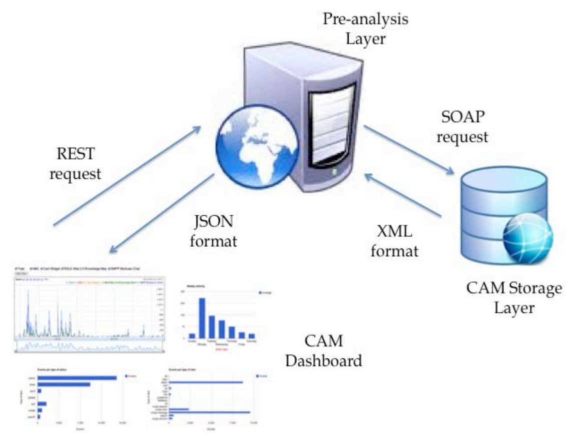

Figure 1 Architecture overview

- *CAM storage layer.* This layer supports storing and retrieving usage data. The information is exposed by a SOAP service developed by Fraunhofer-Institut für Angewandte Informationstechnik (FIT) [7].
- *Pre-analysis layer*. The pre-analysis layer pre-calculates statistics to avoid performance issues when users interact with the dashboard. This layer connects to the CAM storage layer and saves aggregated information in its own database, which is exposed by REST services.
- *CAM dashboard.* The dashboard is implemented in HTML and JavaScript using the Google Chart Tools JavaScript library [2].

Figure 2 shows a typical screen of the dashboard. It contains three visualizations that provide information about *where*, *when* and *what* is happening in learning environments.

- *Where and when:* An annotated time line visualization (Figure 2, visualization labeled with number 2) shows the total activity and the activity of every application over time. The annotated time line at the bottom enables the user to restrict the period of time that the visualization shows.
- *When:* A vertical bar chart (labeled with number 3) shows the average activity by day of the week.
- *What:* The horizontal bar chart with label 4 shows the activity based on the type of action that users perform. The second horizontal bar chart with label 5 shows activity based on the type of resource involved in the action. They can provide information about what kind of actions and resources are popular.

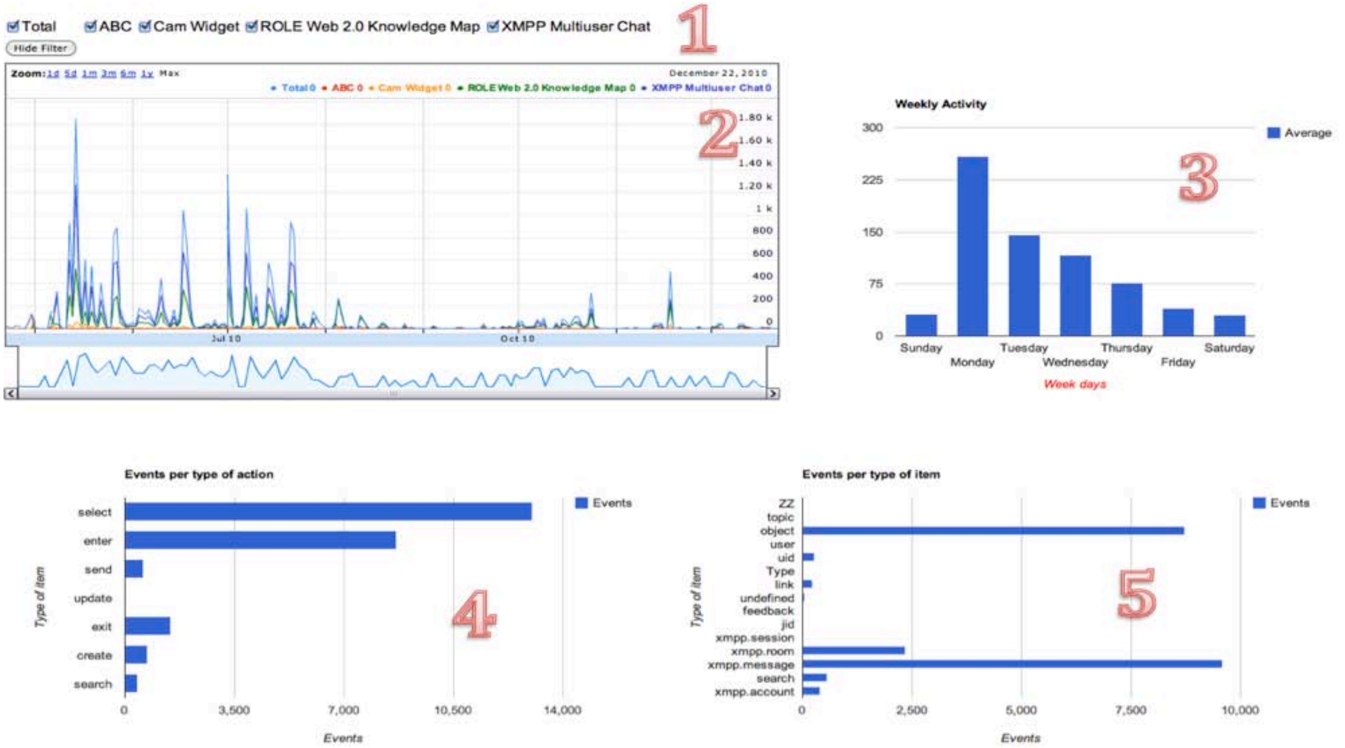

Figure 2 CAM Dashboard overview

At the top of the dashboard (label 1), there is the option of filtering per application. The modification of this filter affects all visualizations. The charts are also interlinked. Table 1 presents which actions trigger updates of other visualizations.

Table 1 Actions overview

Section	*Action triggered*	*Affected visualizations*	*Sent Information*
1	Selecting an application	2,3,4,5	Name of the widget
2	Restricting a period of time	3,4,5	Starting date Ending date
3	Selecting a day of the week	2,4,5	Day of the week
4	Selecting a type of action	5	Type of Action
5	Selecting a type of item	4	

5. USE CASE: XMPP CHAT BEHAVIOR

This use case describes the behavior of a specific widget in a PLE environment, deployed during a course at RWTH Aachen University during the period May to July 2010. After this period, the environment was occasionally used in an informal way. In this PLE, four widgets were used. The widgets use Open Social [13] for their communication in a PLE.

- *ABC Testing widget*. This widget was only used during the first two weeks (this information is also displayed in the dashboard).
- *Cam Widget.* This widget tracks the Open Social communication and translates this communication to CAM. Users can deactivate or activate tracking of their data.
- *Role Web 2.0 Knowledge Map.* This widget allows to search for articles by entering keywords.
- *XMPP Multiuser Chat.* This widget enables chat functionality between different users based on the XMPP technology.

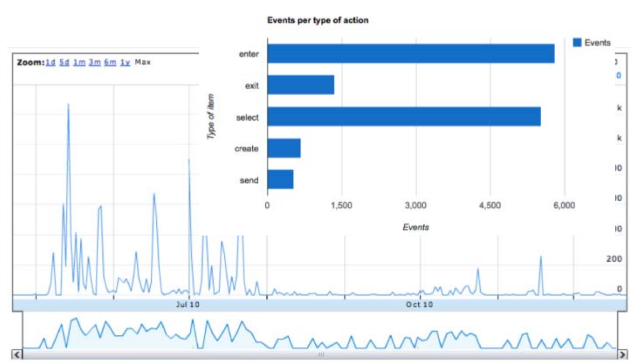

Figure 3 XMPP Multiuser Chat visualization

In this use case, we will focus on the XMPP Multiuser Chat widget because it is the most active in terms of event communication providing us more information about its particular characteristics. We will now explain how we can derive the conclusions from:

1. *Detect changes on usage patterns:* When we select theXMPP Multiuser Chat in part 1 one of Figure 2 and we obtain an overview of the overall activity (Figure 3). The annotated time line chart (Figure 3) enables us to see that the activity was concentrated during the period from May to July 2010. After this period, the activity was reduced considerably. In the "events per type of action" chart (Figure 3), we can see that people enter to room chats more than sending messages (if we zoom into the decreasing period, this behavior is emphasized). A possible reason is that the chat room was not used actively

for communication.

2. *Evaluate whether other similar widgets are affected:* In this use case, other similar widgets do not exist. However, we can compare with the general behavior, selecting the tag "Total" (Figure 2 label 1). We can see that the total activity decreased proportionally to the XMPP Multiuser activity.

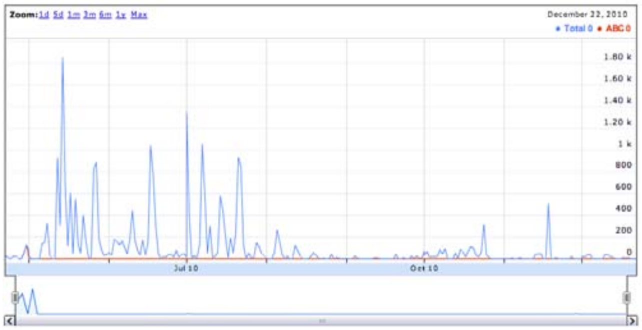

Figure 4 Global activity + ABC activity

3. *Detect which changes have been introduced in the environment:* There are no remarkable modifications. The widget ABC was not used anymore after two weeks, but it did not affect the overall activity (Figure 4). There are no remarkable modifications such as activity of a new widget or the activity of a widget decreasing before the others.

4. *Evaluate how the changes can affect to the first variation in the behavior pattern:* If the activity of one widget decreases before the others, it could point to usability issues with a specific widget. However, the activity always decreases proportionally in all the widgets. In summary, this use case illustrates:

   a. From July to August 2010, there is a remarkable variation of the behavior. During this period, the widgets were progressively less used.

   b. As the activity decreased proportionally in each widget, we cannot identify any of them as the influence of the change.

   c. The visualization of usage data enables to detect usage patterns in the use of widgets and their composition in PLEs. Changes in these patterns can be caused by software reasons, but also by other external influences. In our use case, the external influences were the duration of the course.

6. CONCLUSION

The dashboard is ongoing work, but we have some preliminary conclusions.

Based on ANT premises, the non-human entities have an important role on the software evolution. The dashboard aims to be useful in the detection, variation and explanation of usage patterns as illustrated in the aforementioned use case, so that PLE development can be grounded in feedback loops from analysis of actual use by the intended target users.

Although a specification like CAM provides some interoperability for usage data, problems appear with the semantic interpretation of the information. For instance, if the definition of an action is not agreed upon, then different actions may be merged if they have the same name. Most of these issues can be solved defining some restrictions and using a vocabulary, and providing some technical guides to use the specification. However, this is a difficult trade-off because if the vocabulary management is too restricted, the specification will not be adopted.

An evaluation of the dashboard is planned that will measure the usability and usefulness of the dashboard for such purposes. The current implementation of the dashboard uses real-life data tracked in a computer science course at the RWTH Aachen University. The evaluation will focus on usability quality components [8] such as learnability (how easy is it to work with the tool for the first time?), efficiency (how quickly can users perform tasks?), memorability (do users remember how to work with the tool after a period?), errors (how many errors do users make?) and satisfaction. This evaluation will be conducted with researchers and developers of the ROLE project in a first stage. This evaluation will also be targeted to collect further input about useful visualizations for analytics of PLE usage and evolution.

7. ACKNOWLEDGMENTS

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Applicability of the Technology Acceptance Model for Widget-based Personal Learning Environments

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ABSTRACT
This contribution presents results from two exploratory studies on technology acceptance and use of widget-based personal learning environments. Methodologically, the investigation carried out applies the unified theory of acceptance and use of technology (UTAUT). With the help of this instrument, the study assesses expert judgments about intentions to use and actual use of the emerging technology of flexibly arranged combinations of use-case-sized mini learning tools. This study aims to explore the applicability of the UTAUT model and questionnaire for widget-based personal learning environments and reports back on the experiences gained with the two studies.

Keywords
Acceptance, Personal learning environment, Widgets

1 INTRODUCTION
A personal learning environment can be modelled as a network of people surrounding an individual with the persons in this network making use of artefacts and tools while they engage in isolated or collaborative activities of more or less planful (co-) construction of knowledge and information (cf. Wild et al., 2008a). The individual at the centre actively and passively modifies this environment through actions with the intention to positively influence her social, self, methodological, and professional competence, i.e. changing her potentials for future action.

Though the individual tries to structure the environment, she is not fully in control to design it, as interactions of the agents in the network (persons, tools, artefacts) are not working towards a common goal or joint plan. Moreover, affordances and characteristics of its agents moderate performance and behaviour in this fragile ecosystem. Even where parts of this environment are subjected to user control, for example in selection and use, this is largely influenced by attitudes, norms, expectations, intentions, and the like.

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Widget-based personal learning environments provide a technology for meeting these heterogeneous requirements better. They challenge the dominant design of classical managed learning environments offered by institutions and open up environments for flexible recombination of their elements (Wilson et al., 2011).

Widgets are encapsulations of logical user interface units, i.e. “dialogue-sized visual appearances with a particular, use-case sized behaviour” (Wild et al., 2008b). In other words, widgets are the logically partitioned, deconstructed user interface units of learning content management systems and other types of learning tools. In their minimalist seclusiveness they are expected to maximize the potential for re-use and complement achievements of personalized navigational adaptation of the recent years with means to personalise the environment now also on the presentation layer. Figure 1 presents such a widget-based PLE in action: in two columns, six widgets are presented that facilitate an overarching task. In this PLE, learners would first find suitable resources through the search widgets in the column to the left, then summarise the identified texts in PenSum (top right) into a synthesis, for which Conspect (bottom right) provides further feedback on conceptual knowledge covered in comparison with peer learners.

Widget-based PLEs have evolved over recent years into mature technologies and infrastructures (Wild et al., 2008b; Wilson et al., 2011). Within this contribution, we investigate, whether we can apply the predictions about acceptance and use provided by the UTAUT model to the domain of widget-based PLEs.

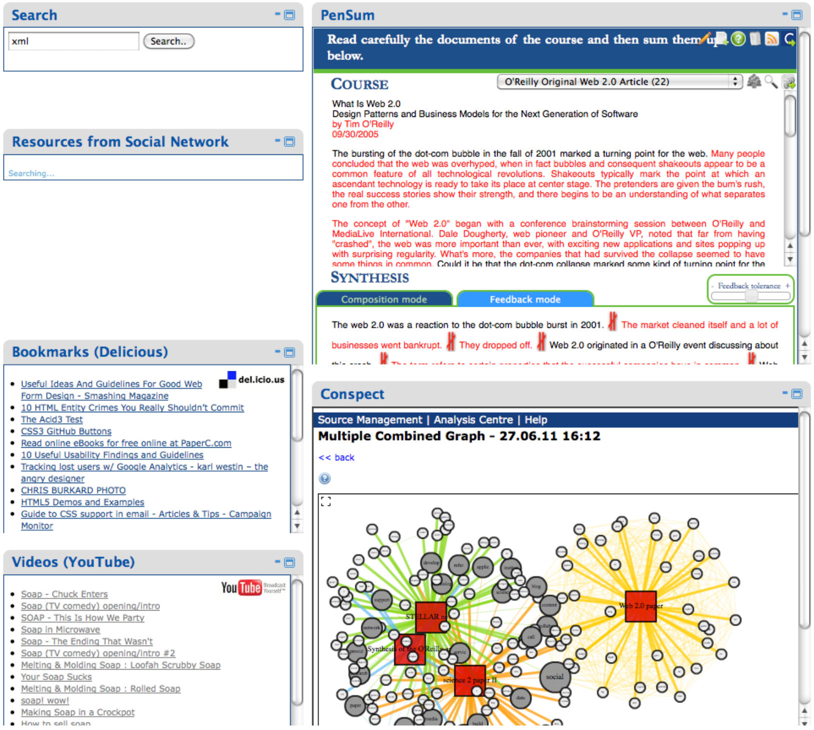

Fig. 1: A widget-based PLE in action.

The determinants of acceptance and use have been studied in several models – the unified theory of technology acceptance and use of technology (UTAUT) being one of the most elaborate (see Venkathesh et al., 2003). UTAUT has been elaborated from a set of eight prominent models for information technology acceptance research and has been found to outperform these precursors with respect to the ability to explain user intention to use information technology (Venkatesh et al., 2003).

The determinants identified in the unified theory relate to individual reactions to technology such as expressed expectations, assessed social pressure, and other types of statements about influencing factors, that are known to drive the intention to use and – ultimately – actual use behaviour (see Figure 2). Together, the variables of the model have been found to explain about 70% of the variance in user intention to use particular technologies (Venkatesh et al., 2003).

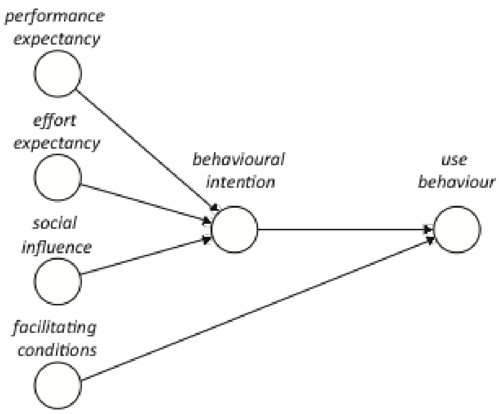

Fig. 2: Direct and indirect determinants of user acceptance and usage behaviour.

The model breaks these determinants down into performance expectancy, effort expectancy, and social influence that are found to be driving the behavioural intention to use (see Figure 2). Furthermore, the behavioural intention and facilitating conditions are found to be predicting actual use. Additional factors such as attitudes towards technology, computer self-efficacy, and computer anxiety have been investigated, but their effects are being captured by effort expectancy. Additionally, moderators of the indirect drivers of actual use have been identified. For this study, moderators, however, have been neglected, as they were not of interest.

Within this contribution, two exploratory studies about acceptance and use of widget-based personal learning environments are presented. With the means of the UTAUT model, the first study investigates acceptance of a technology-affine group of technology-enhanced learning researchers, whereas the second study looks at students. It is thus not very representative of typical learners or facilitators, but still arguably inspects acceptance among a group of early adaptors. Its aim was to try out the applicability of the UTAUT model and method as a sort of pre-test for a follow-up study. As a side effect, however, it may provide valuable insights into what these groups think about emerging technology.

2 METHODOLOGY

For the first study, a hands-on session was prepared for participants of a workshop held at the Joint European Summer School in Technology-Enhanced Learning (JTEL'10). The session focused on constructing a personal learning environment in form of a paper prototype. The participating 13 doctoral candidates and mentors were first briefed on the widget approach as such and with the help of selected widgets from the language technology for lifelong learning (LTfLL) project on typical use-cases of individual widgets. Each group was then provided with empty flipchart paper (representing an empty widget container) and with printed and blank widget cards, which they could use to populate their own widget space. They were instructed to discuss and create a personal learning environment with the help of these materials. The group session lasted for about 45 minutes and finished with a group presentation of the PLE created back to the plenum. Afterwards, the participants were asked to fill in the technology-acceptance questionnaire.

The second study took place at the University of Bukarest, with 25 computer science students participating. The students were working for one day with an elgg-based implementation of a personal learning environment (Wild et al., 2010) to achieve certain given tasks (see snapshot of the system in Figure 1[1]). Afterwards, they filled in the questionnaire.

The questionnaire deployed consisted of a set of items, which were minimally adjusted from the original questionnaire of Venkatesh et al. to fit to the scenario of widget-based PLEs. Besides the core constructs mentioned above, additional questions were included to collect data on moderating variables.

The items of the questionnaire are grouped into five sets (see Table 1), supported by questions on moderating variables such as gender, age, highest level of education, employment, and generic questions about computer and internet usage skills. These five constructs cluster together items on expectations on performance gains (PE) and efforts to be invested (EE), statements assessing whether there is social pressure pushing forward the use of widget-based PLEs (SI), availability of support and resources necessary (FC), and – finally – intentions to use (BI).

[1] The system can be accessed at http://augur.wu.ac.at/elgg/; an openID is required for the full functionality to work.

Table 1: Questionnaire items (without moderating variables)

Performance Expectancy (PE)	*U6*	I would find the system useful in my job.
	RA1	Using the widget-based PLE enables me to accomplish tasks more quickly.
	RA5	Using the widget-based PLE increases my productivity.
	OE7	If I use the widget-based PLE, I will increase my chances of getting a raise.
Effort Expectancy (EE)	*EOU3*	My interaction with the widget-based PLE would be clear and understandable.
	EOU5	It would be easy for me to become skillful at using the widget-based PLE.
	EOU6	I would find the widget-based PLE easy to use.
	EU4	Learning to operate the widget-based PLE is easy for me.
Social Influence (SI)	*SN1*	People who influence my behaviour think that I should use the widget-based PLE.
	SN2	People who are important to me think that I should use the widget-based PLE.
	SF2	The senior management in my institution has been helpful in the use of the widget-based PLE.
	SF4	In general, the organization has supported the use of the widget-based PLE.
Facilitating Conditions (FC)	*PBC2*	I have the resources necessary to use the widget-based PLE.
	PBC3	I have the knowledge necessary to use the widget-based PLE.
	PBC5	The widget-based PLE is not compatible with other systems I use.
	FC3	A specific person (or group) is available for assistance with widget-based PLE difficulties.
Behavioural Intention (BI)	*BI1*	I intend to use the widget-based PLE in the next 12 months.
	BI2	I predict I would use the widget-based PLE in the next 12 months.
	BI3	I plan to use the widget-based PLE in the next 12 months.

3. ANALYSIS OF RESULTS

Within this section, results of the two studies will be reported. The section will start with an overview in form of descriptive statistics on the grouped items as proposed in the unified theory of acceptance and use of technology. In a second step, the item-item reliability of the constructs used is measured with Cronbach's α to gain insight into whether the questionnaire items of the model chosen in fact converge in the groups proposed. Since this was not the case, we calculated a factor analysis after exclusion of unreliable items to see if the groups predicted by theory are reflected in the empirical data gathered in the two studies. The results indicate that the grouping as proposed in the underlying model can be justified, though alternative ways of clustering would be possible. A correlation analysis rounds up the section.

For all items of the questionnaire, **basic descriptive statistics** were calculated as listed in Table 2 and 3, thereby taking into account the average of the items for each construct. As visible from Table 2, the users rated the expected benefit for performance using widget-based PLEs with moderate 3.33 in the first study. The effort expected is rated with 3.88, which means that the users think that this approach makes it moderately easy to achieve their goals. The social influence has the lowest average with 2.98: users slightly tend to agree to being socially influenced by others to use this approach. The facilitating conditions are rated moderate high, which could express that users have the resources and the knowledge to use the system, but additional improvements of support are possible. The intention to use the system in the next 12 months is moderately high.

Table 2: Descriptive statistics of the raw data of the first study

	N	*min*	*max*	*mean*	*std.dev.*	*var*
Performance Expectancy	13	1.75	4.50	3.33	.78	.61
Effort Expectancy	13	3.25	4.75	**3.88**	.56	.32
Social Influence	12	1.75	5.00	2.98	.93	.87
Facilitating Conditions	13	2.50	4.25	3.48	.53	.29
Behavioural Intention	13	1.00	5.00	**3.43**	1.20	1.43
Valid N (listwise)	12					

The second study shows similar means compared to the first one. One notable exception can be found in the items aggregated under behavioural intention to use. While in the first study the mean was slightly higher than the average (3.43) in the second study the mean is lower (2.79).

Table 3: Descriptive statistics of the raw data of the second study

	N	*min*	*max*	*mean*	*std.dev.*
Performance Expectancy	25	2.00	5.00	3.23	.75
Effort Expectancy	25	1.25	5.00	3.56	.94
Social Influence	21	1.50	4.00	3.08	.68
Facilitating Conditions	23	2.50	4.75	3.55	.55
Behavioural Intention	24	1.00	4.67	2.79	.99
Valid N (listwise)	20				

To investigate the quality of the questionnaire in this context of widget-based PLEs, the **inter-item reliability** was calculated using Cronbach's α to detect whether the items correlated high amongst each other in each given construct. If inter-item reliability is found to be high, this would express that the items of each construct are in line with the theoretical model proposed in the UTAUT.

In the *first study*, 'performance expectancy' consists of the four items U6, RA1, RA5, and OE7 – and Cronbach's α for these four items is .76. While three items have a high inter-item correlation, the correlation of OE7 is weak for all other items. If OE7 is excluded Cronbach α rises to .95. The item "If I use the widget-based PLE, I will increase my chances of getting a raise" seems not to fit the other three items, which target the usefulness of the system for the job, to accomplish tasks, and to increase the productivity. Since the target groups investigated were early career and more advanced researchers in this first data set, this finding is not very surprising: other performance will rather less directly impact on salaries in an academic setting than in a business.

Analyzing the items of the 'effort expectancy' (items EOU3, EOU5, EOU6, and EU4) finds a Cronbach's α of .83: the inter-item correlation matrix shows low correlations of the item EOU3 with the other items. Although all four items are directed towards ease of use and easiness to understand the system, the item "My interaction with the widget-based PLE would be clear and understandable" (EOU3) seemed to be not properly formulated. Even though Cronbach's α rises to only .88, EOU3 will be excluded from the further analysis as for its low correlation with the other items.

The factor 'social influence' consists of the four items SN1, SN2, SF2, and SF4. Removing item SF4 would raise Cronbach's α only from .80 to .86 and thus the item will not be excluded from the further analysis.

Analyzing the items for the factor 'facilitating conditions' (PBC2, PBC3, PBC5, and FC3), Cronbach's α loads with .29 rather low. After the exclusion of FC3 and PBC5, which both correlated low with all other items of this factor, Cronbach's α rises to .79. While PBC2 and PBC3 ask about resources and knowledge to use widget-based PLEs and are positive formulated, the item PBC5 "The widget-based PLE is not compatible with other systems I use" is negative formulated", which could be the reason for its low correlation with the other items. The item FC3 asks if assistance is available for using the system. While the first two items could be seen more as in control of the individual, the last item contains a social component, which could have led to the low correlation with the other items.

The items of the factor 'behavioural intention' have a high Cronbach's α of .96.

In the *second study*, the items for 'performance expectancy' (U6, RA1, RA5, OE7) have a high inter-item reliability (Cronbach's α = .84). While in the first study we excluded the item OE7 for the further analysis, we will keep it for the second study.

The items for 'effort expectancy' (EOU3, EOU5, EOU6) have a Cronbach's α of .89 (.92 if EOU3 deleted). While we excluded EOU3 from the first study, we will include it for the following analysis, due to the only small gain of the Cronbach's α, when removed. This could indicate that the item EOU3 should be reformulated in further studies.

Amongst the items for 'social influence', Cronbach's α of SN1, SN2, SF2 and SF4 is .76. This is in line with the results of the first study.

Cronbach's α for the 'facilitating conditions' (PBC2, PBC3, PBC5, FC3) is again rather low (.28). After the exclusion of PBC5, it rises to .49 (and with FC3 excluded to .93). This is similar to the first study and could be seen as a hint to reformulate or to drop these items in future studies.

The 'behavioural intention' items (BI1, BI2, BI3) have a high Cronbach's α of .91.

Except for the items EOU3 and OE7 that will be kept for this second data set, we could repeat the results of the first study regarding the inter-item reliability: both studies identify a problem for two items in the facilitating conditions; these two items PBC5 and FC3 should be dropped or reformulated in future studies.

In the next step, we apply a **factor analysis** to detect if the constructs as grouped by the UTAUT model are also reflected in factors for our data sets. Therefore, we first tested the statistical requirements for normal distribution, which is a precondition for the conduction of an exploratory factor analysis. The Shapiro-Wilk tests indicate that normal distribution is only given for the items RA1, RA5, SN1, SN2, SF2, PBC2, and BI3 of the first study. The Shapiro-Wilk tests for the second data set indicate that normal distribution is only given for the items OE7, BI2 and BI3, compared to RA1, RA5, SN1, SN2, SF2, PBC2, and BI3 for the first study. This has to be taken into account for the interpretation of the following factor analysis, which should be only applied if all items are normal distributed. However, since the goal of this study is to gain experience with the UTAUT model and to further develop the questionnaire, the results are still considered relevant, but have to be interpreted with precaution.

According to the UTAUT model, all factors (= groups of items) should be more or less independent from each other. To test this assumption on our data, a factor analysis with varimax rotation was calculated, providing means to investigate whether the items load on factors as suggested by their theoretical underpinnings.

The pre-analysis of the *first study* resulted in a non-positive correlation matrix, which normally indicates the need of a bigger sample size. The scree plot would suggest a two- or three-factor solution. To investigate, however, the closeness to the theoretically postulated clustering, the rotated factor analysis calculated with the five factors (as indicated by the UTAUT model) shows the results presented in Table 4.

The three items for performance expectancy (component 1) as well as for effort expectancy (component 2) and social influence (component 3) load high on factors, see Table 4. This can also be found for two out of the three variables for behavioural intention (see component 4) and for one variable of the facilitating conditions (see component 5). According to the rotated factor analysis, however, PBC3 loads high on the factor of effort expectancy, and BI1 high on the factor of the performance expectancy items. Still, the general picture is that the items of our first study load on factors similar to the factors predicted by UTAUT.

Based on these findings of the factor analysis, the items with high inter-item correlations and high level of independence as suggested by the factor analysis will be used for the final next step of the analysis: the calculation the correlations of the UTAUT factors. For the first study, performance expectancy consists of the items U6, RA1, and RA5. Effort Expectancy consists of the items EOU5, EOU6, EU4 and social influence of the items SN1, SN2 and SF2. Only the item PBC2 of the facilitating conditions remains, and the items of the behavioural intention to use are BI2, and BI3.

Table 4: Rotated component matrix for the first study

	Component				
	1	*2*	*3*	*4*	*5*
U6	.953	.003	-.191	.157	-.026
RA1	.841	.380	-.211	.125	.190
RA5	.897	-.039	-.224	.132	-.196
EOU5	.407	.737	.404	.006	.100
EOU6	.120	.909	.084	.248	.269
EU4	-.111	.970	.111	.005	-.117
SN1	-.180	.362	.779	-.356	.146
SN2	-.602	.015	.606	-.056	.424
SF2	-.359	.222	.786	.014	.090
PBC2	-.353	.332	.385	-.189	.731
PBC3	.165	.692	.438	-.374	.288
BI1	.883	.066	-.048	.320	-.306
BI2	.690	.172	-.171	.651	-.199
BI3	.567	.076	-.154	.796	-.064

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 9 iterations.

The pre-analysis of the *second study* revealed that the Kaiser-Meyer-Olkin of the partial correlation coefficients is relatively low with 0.4 (values higher than .5 are seen a condition for calculating a factor analysis). However, the Chi-Square value of Bartlett's test is high (288,45; df = 136) and the probability of an error is low. As in the first study, the requirements for a factor analysis are not satisfied. As the goal of the study is to find hints for the construction of the next questionnaire, the factor analysis was calculated as it could help to determine if certain items should be assigned to another construct of UTAUT or not.

The Scree Plot of the factor analysis suggests a five or six factor model for the second study. Looking at the percentage of how much each component explains the variance, the first five components have an eigenvalue higher than 1 and explain 82.66 % of the variance. In the following, we will focus on a 5-factor model, which would be in line with the UTAUT model, and is also justifiable with the results from the scree plot as well as the high percentage of explained variance.

Based on these results we calculated a factor analysis with five fixed components with varimax rotation. The result is presented in Table 5.

Table 5: Rotated Component Matrix of the second study

	Component				
	1	*2*	*3*	*4*	*5*
U6	.517	.118	-.393	.679	-.090
RA1	.406	.610	.317	.394	-.171
RA5	.045	.649	.371	.582	-.160
OE7	-.124	.157	.144	.889	.099
EOU3	.425	.036	-.100	.293	.724
EOU5	.849	.103	.227	-.203	.095
EOU6	.712	.310	.227	-.087	.332
EU4	.759	.329	.191	.045	.293
SN1	.116	.279	.387	-.191	.722
SN2	.111	.595	.289	-.120	.533
SF2	-.103	-.044	.832	.093	.313
SF4	.037	.045	.936	.030	-.028
PBC2	.118	.915	-.082	.067	.146
PBC3	.026	.888	-.134	.151	.184
BI1	.888	.021	-.092	.104	-.064
BI2	.840	-.004	-.151	.100	.023
BI3	.837	-.011	-.193	.074	.204

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 18 iterations.

The results of the rotated component matrix are less conclusive as in the first study, but can be interpreted when having the factors of the UTAUT model in mind.

The items RA1, RA5 of the performance expectancy load high on component 2, while the items U6, RA5 and OE7 load high on component 4. As the items PBC2 and PBC3 of the Facilitating Conditions load high on component 2 as well, we will take into account for the further analysis the items U6, RA5 and OE7 of component 4.

The items of the effort expectancy (EOU5, EOU6, and EU4) load high on component 1, while EOU3 loads high on component 5. The items of the effort expectancy and the behavioural intention to use load high on the same component 1.

Only the items SF2 and SF4 of the social influence variable load high on component 3, whereas SN1 loads high on component 5 and SN2 on component 2.

Based on the results of the inter-item reliability and factor analysis, the items RA1, EOU3, SN1, SN2, PBC2 and PBC3 were excluded.

After the application of the inter-item reliability and the factor analysis, we calculated again the **descriptive statistics**. This time it takes into account the findings from the above-mentioned analysis steps and thus represents a cleaner model of the data. For the *first study*, the items of each construct were aggregated again and basic descriptive statistics were calculated (see Table 6).

Table 6: Descriptive (refined) statistics of the first study.

	N	*min*	*max*	*mean*	*std.dev.*	*var.*
Performance Expectancy	13	1.67	5.00	3.64	1.04	1.08
Effort Expectancy	12	3.00	5.00	4.00	.70	.48
Social Influence	11	1.00	5.00	2.97	1.11	1.23
Facilitating Conditions	12	1.00	5.00	3.42	1.22	1.49
Behavioural Intention	13	2.50	5.00	4.00	.79	.62
Valid N (listwise)	11					

The results of the descriptive statistics, using the refined set of items, show slightly higher values as compared to the first descriptive statistics. Especially the effort expectancy and the behavioural intention to use the system with a mean of 4.0 and relatively low standard deviations are indicators that the users of the scenario would use the system and they perceive it as easy to use.

Table 7: Descriptive statistics of the refined data set of the second study.

	N	*min*	*max*	*mean*	*std.dev.*
Performance Expectancy	25	2.00	5.00	3.20	.79
Effort Expectancy	25	1.00	5.00	3.64	1.04
Social Influence	21	2.00	5.00	3.36	.84
Facilitating Conditions	25	3.00	5.00	4.50	.63
Behavioural Intention	24	1.00	4.67	2.79	.99
Valid N (listwise)	20				

For the *second study*, the results of the descriptive statistics show a slightly different picture than in the first study. The facilitating conditions with a mean of 4.5 are more than one point higher than in the first study (3.42). And the behavioural intention to use was high in study 1 (mean of 4.0) it is lower in the second study (2.8). The other constructs have a similar mean in both studies.

In a further analysis step, we calculated the **correlations** between the constructs as proposed in UTAUT. First, we examined the normal distribution as a precursor for the Pearson test.

The Shapiro-Wilk test for normal distribution indicates normal distribution for each of the aggregated components of the *first study*. With normal distribution given, the Pearson correlation (one tailed) was calculated for each of the aggregated components. The results are the following. The correlation between Performance Expectancy and the Behavioural Intention are low (r = .14; not significant). The correlation between Effort Expectancy and Behavioural Intention is medium (r = .54*). There is a high correlation between the Social Influence and the Behavioural Intention (r = .76**).

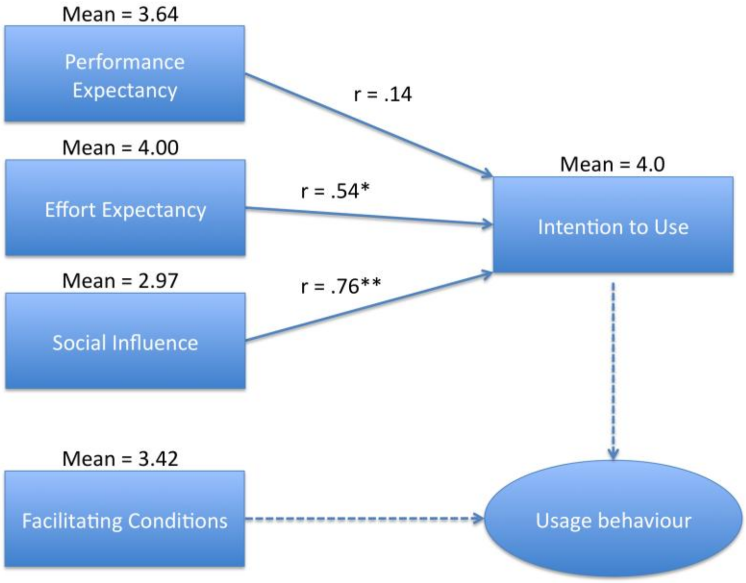

Fig. 3: Correlations of the cleaned data set of the first study.

A Structural Equation Model was calculated using AMOS, but did not lead to statistically satisfying results, although tested with a variety of models. This can be attributed to the relatively small sample size.

Regarding the *second study*, except from the facilitating conditions, the Shapiro Wilk test indicated normal distribution, which leads to the decision of using the Pearson Correlation (one-tailed).

The correlation between effort expectancy and the behavioural intention to use was the only significant one with r = .60; all other correlations were not significant. This value is similar to the one in the first study (r = .54). The significant correlation between social influence and intention to use could not be replicated.

A **Structural Equation Model** was tested with AMOS, taking into account the reduced set of items (refined with the insights from the inter-item reliability analysis and the factor analysis). The model, however, was not admissible. The AMOS model calculated with all items produced output, but was not admissible. This can be attributed to the small number of participants in the studies. A follow up study would shed further light on this.

4. CONCLUSION AND LIMITATIONS

The paper presents results about the applicability of the technology acceptance model as proposed in UTAUT – adapted to the context of widget-based Personal Learning Environments. The UTAUT questionnaire can be seen as an instrument to assess whether users are highly likely to actually use a widget-based PLE. The acceptance model predicts a high probability of use if the construct behavioural intention and the facilitating conditions are high. In two studies, we applied this method with the goal to gain experiences with this instrument and to tailor the questionnaire to the context of widget-based PLEs. Both studies found high and moderately high values for the facilitating conditions (study one: 3.42, study two: 4.50, see Tables 6 and 7). With regards to the behavioural intention to use, the two studies differed: whereas study one found with 4.0 moderately high values, study two was 2.79 rather average. As the data sets were relatively small, these findings cannot be generalised and must be handled with precaution.

The results have been encouraging, but it also became clear, that the model (and questionnaire) couldn't be mapped directly to the domain of PLEs. Both studies show in their inter-item reliability and factor analysis, that the components of the original UTAUT model can be more or less confirmed. These methods, however, also revealed potential to improve the model and questionnaire when applied to study acceptance of PLEs. The reason why the structural equation model was not admissible in both studies seems to lie in their relatively small number of participants. However, further research is needed to gain experience about a practical sample size. This is especially important for the validation of an acceptance model for PLE scenarios.

Although technology acceptance studies are widely used, studies from one domain cannot be compared with the domain of investigation without limitations. To build up a strong argument about the explanatory power of this study, a baseline from a similar study setup would be required.

Furthermore, as Al-Qeisi (2009) summarises, the results are limited in so far as they base on self-reports of users, but not on their actual use. In other words, further tests to check validity against the criterion actual usage would be helpful.

Additionally, another limitation can be found in the selection of participants for this study: one important moderator effect we have to consider is, that both samples consisted of technically skilled persons. They can be seen as early-adopters or innovators of new technology. Yet, this group of people does not necessarily represent the larger group of people who are less technology affine. It is hard to predict how these results will change, when turning to people with other backgrounds.

As the goal of the study was to test if the technology acceptance model is applicable for the domain of PLEs, as such the results of the first two studies can be seen as promising for further work to refine the method. The results, however, should not be mistaken as statements about the general usefulness of PLEs according to the UTAUT model. These statements would be misleading in this early research stage of the validation of the technology acceptance model and its instrument for PLEs.

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A Software Project Perspective on the Fitness and Evolvability of Personal Learning Environments

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ABSTRACT

This position paper deals with the exploration of fitness and evolvability of personal learning environments (PLEs). Taking a software engineer's perspective, PLE evolution is a software project. Software quality characteristics like Functionality and Usability map to the PLE's *fitness*, while Maintainability is important for *evolvability*. Only adaptation can secure future fitness. But for this, the software project has to be a good PLE for its developers in its on right.

1. INTRODUCTION

Common wisdom of software development — going back to Edward V. Berard — says: *"Walking on water and developing software from a specification are easy if both are frozen."* The success of Personal Learning Environments (PLEs) not only depends on their fitness for a certain purpose or environment, but no less than this depends on their ability to evolve, i.e. to adapt to changes. In the world of software, the continuous change of requirements is as sure as death and taxes. A PLE that fails to catch up with new requirements, ages and eventually becomes useless.

Bear with me, while I relate to the workshop's natural evolution metaphor: The extinction of dinosaurs is attributed to their failure to adapt to a changing environment. Their races showed only few diversification and innovativeness in behavioral strategies. When their world changed, only two species attempted an adaptation to new foods [6]. The dinosaurs' seemingly unbreakable predominance abruptly ended, making room for mammals that had waited in a niche. Mammals instantly filled the gap, and diversified into a plethora of species. Today, they emboss the planet's face as successful predators. If dinosaurs had not failed to adapt, they would have remained invincible competitors for any other species.

Predominance and wide spread were limited predictors of fitness and evolvability. Predominance can suppress competitors, but for how long? It is no disgrace to wait for a chance like the early mammals. To avoid extinction and eventually prevail, PLEs must evolve. Different from nature, where mutation of organisms occurs by accident and without the intent to optimize a creature's fitness, adaptation happens through conscious decision and human developers.

I take on a software engineer's view in the discussion on *fitness* and *evolvability* of PLEs. In this view, evolvability E is understood as a PLE's ability to embrace natural change, i.e. evolution E'. Fitness F does not imply evolvability, nor does evolvability imply fitness. Yet both are prerequisites of successful evolution $F \wedge E \Leftarrow E'$. New clades of PLEs often start from research. While fitness is usually tested thoroughly there, evolvability is often neglected.

The easier developers perform changes, the higher the chance that a PLE will cope with emerging requirements. Only this can make a PLE remain fit. Section 2 addresses the *ease of change* in software projects. This leads to the finding that learning is essential, and to the dualism that evolution is a PLE itself (Section 3). As long as a PLE's fitness suffices to safe it from extinction, evolvability is most important. A more evolvable PLE will adapt to changing environmental demands faster and easier. In conclusion, this is not least a matter of how easy PLE developers can obtain the necessary knowledge to make change happen.

2. EMBRACING THE CHANGE

Evolvability means to be prepared for changing environments and the unknown. It cannot be said in an across-the-board fashion what that practically means. It would imply to summarize the achievements of software engineering in a few sentences. In the Iron Triangle, the prime resource is *people* supported by *processes* and *technology* [5]. A full discussion of all three factors would be way out of scope of this paper. Instead, here are some fundamental considerations:

Whenever a software system grows larger, its complexity increases to a level that is no longer easily handable. Any successful software will eventually grow to that size. Abstraction and structuring that organize it into an understandable *architecture* become necessary. A good architecture means that developers can change parts without having to understand everything. But for the individual developer, having to adhere to architecture rules can be cumbersome. In a multi-tier Web-Service project, developers of front-end components bypassed the middle layer, and directly accessed back-end layers. This sped up development at first, but degraded architecture to a costly mess. Evolvability assessment should take into account how an architecture is protected, and how technical debt (see also [1]) is dealt with.

The term *architecture* should not be confused with integration platform. An integration platform can be something like UNIX's toolbox concept with its many small programs. It can be Web-Services, or a single program based on OSGi. The different platforms have different strengths and weaknesses that influence PLE fitness. Yet from an evolvability point of view, they are similar, all allowing fast adaptation through reuse of components. Do not think that a technology has reuse built in; instead, reuse is a discipline [12]. Here, it is more important to look at the processes.

Even with the best architecture, building a software architect's knowledge costs a hundred million. The combination of deep domain knowledge and system engineering capabilities is invaluable [2]. Will the architect stay with the PLE project? What endeavors are made to train new architects?

Is the business model associated with the PLE project sustainable? While a potent company may be able to handle closed-source evolution on its own, also the openness of open source — mind the license — has advantages for evolvability: open standards, interoperability, cost effectiveness, attractiveness for users, possibly unlimited branching and experimentation, and a higher number of potential developers. However, a major road block to becoming a productive executor of PLE evolution, is knowledge about the software.

The Maintainability quality characteristic describes a software's capability to be modified and evolve [4]. By being analyzable, easy and predictable to change, and allowing to test changes, software developers can gain a deep understanding of the software through practical experimentation.

All of the aspects in the paragraphs above, help developers to understand the software by being few (complexity-reducing architecture), simple (with reuse in mind), supervised (senior architect guidance), open (open source), and practical (support experimentation) to learn. Knowledge about the software project, i.e. about how to evolve the PLE, is at the center of evolvability. Not only is the process of PLE evolution a software project, but a software project is a PLE itself. This duality is addressed next, when we look at internal documentation, which can be considered as the learning material that supports learning a software system.

3. THE SOFTWARE PROJECT AS A PLE

Modern software systems are too complex to fully understand them. But a certain understanding is necessary for performing changes. Working on a computer system is therefore a continuous learning process. The learning materials are process artifacts like source code, requirements, bug history, etc.; a developer's PLE consists of his individual selection of source code pieces, requirements, searchable bug records and so on that are delivered to him through tools like an IDE or an issue tracker. Developers do not like to create such learning material because it has few value for them [9]. But it is needed to persist collaborative long-term efforts like developing and maintaining a software.

Consider the example of source code (see also [7]): Source code is mostly learning material for us humans. There is an infinite number of ways of writing a same-purpose computer program. Neither does it matter for a computer what programming language one uses, nor does a parser care how functions and methods are named. The instructions that the computer needs are intertwined with the human-readable lines of source code. Functions, data types, objects, comments, macros, etc. and their respective names are just abstractions that make the design appear more clearly from code by masking unneeded implementation details [10]. This way we humans better understand what the computer will do. Programming languages exist so that we can better explain to our fellow developers what the computer will do.

In a small, one-person, throw-away-prototype project it may be sufficient to just code, but any other project will eventually need documentation [11]. The actual way of how code is documented is less important, as long as all the necessary information is conveyed. The difference that matters is that between hacking code quick and dirty, or being nice to fellow developers by making code easier to understand by investing a little more effort. Source code — originally a medium of communication between man and machine — has become a medium of communication among humans [3].

Documentation (as learning material) communicates background, context, and trial-and-error information. This information is extremely valuable [8], but will get lost if not preserved. Motivating developers to create good learning material is a key to evolvability and survival of PLEs.

4. CONCLUSION

Evolvability is important for the success of a PLE, because it allows to adapt it to new environments, and thus stay fit. PLE evolution happens through a software project. Developers, who realize the change of evolution, require a certain knowledge of the software for this. Evolvability then is the availability and ease of obtaining the necessary knowledge.

After all, a PLE's evolution, i.e. its software project, is a PLE in its own right. This duality between software projects and PLEs is the key to evolvability, and future fitness. Does the software project make a good PLE for its developers? If yes, then a big obstacle to survival is cleared out of the way.

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Contextual Factors in the Adoption of Social Software: A Case Study

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ABSTRACT

This paper presents the results of a small field study to identify major barriers to adoption of a social software tool. Gleanr is a Web 2.0 application that can be used for group information management, social bookmarking, and personal research and branding. We present a brief overview of the software and its affordances, describe the study, and reflect on the results as we discuss lessons learned from our first pilot deployment.

1. INTRODUCTION

Over the past decade, social computing has emerged immensely as a phenomenon among distributed communities. The benefits of social systems depend on a large part on the existence of an active user community who use it continuously to deploy and share information. However, while certain systems have enjoyed tremendous success (Facebook, twitter), others have experienced modest adoption at best. It is not clear what factors contribute to the rise and fall of these systems. This paper is a report on our experience with the deployment of a social software tool and our attempts to identify the major barriers to its adoption. We first introduce the system, Gleanr [6], and describe our research methodology. Based on our findings, we propose a set of contextual factors for successful adoption of such tools. While small-scale, our study might provide some insight on how to design social software systems with better chances of wide adoption.

2. GLEANR

Gleanr is an online personal information management tool that allows users to control their web presence. The main idea behind Gleanr is that with today's vast array of social tools (blogs, twitter, Facebook, etc.), modern knowledge professionals are faced with too many output streams to fill and too many input streams to follow. Gleanr provides means to automate one's web flow through customized Gleanr channels. Here is how it works:

Upon finding something interesting or relevant to their current activity, users can select the exact content and add it to their Gleanr account by clicking the Gleanr bookmarklet on their browser (figure 1). At the same time, they can edit, tag, and set access rights on the captured content. As a result, not only the content will be saved in Gleanr, but also depending on how the user has set his/her account, the newly captured content will also update his/her tweeter, Facebook, and/or LinkedIn status. Users can also subscribe to the information streams of others if they are interested. Gleanr then aggregates, indexes, and networks all of one's captured or created information. Considering these functionalities, Gleanr can be used as a personal information management tool, a personal research assistant tool, a personal branding tool, or a collaborative tool. Figure 2 shows a screen shot of a series of "gleans" created by various users in Gleanr.

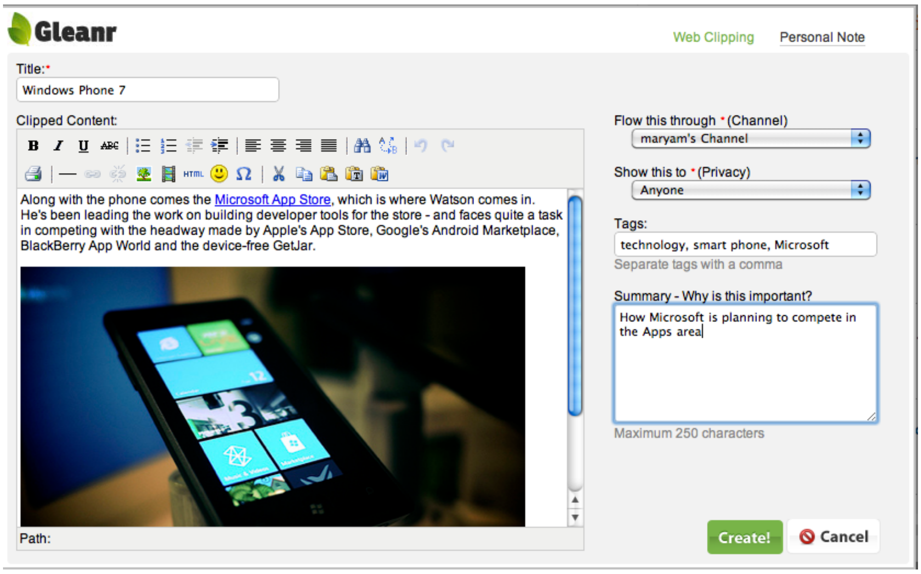

Figure 1. Capturing content as a "glean"

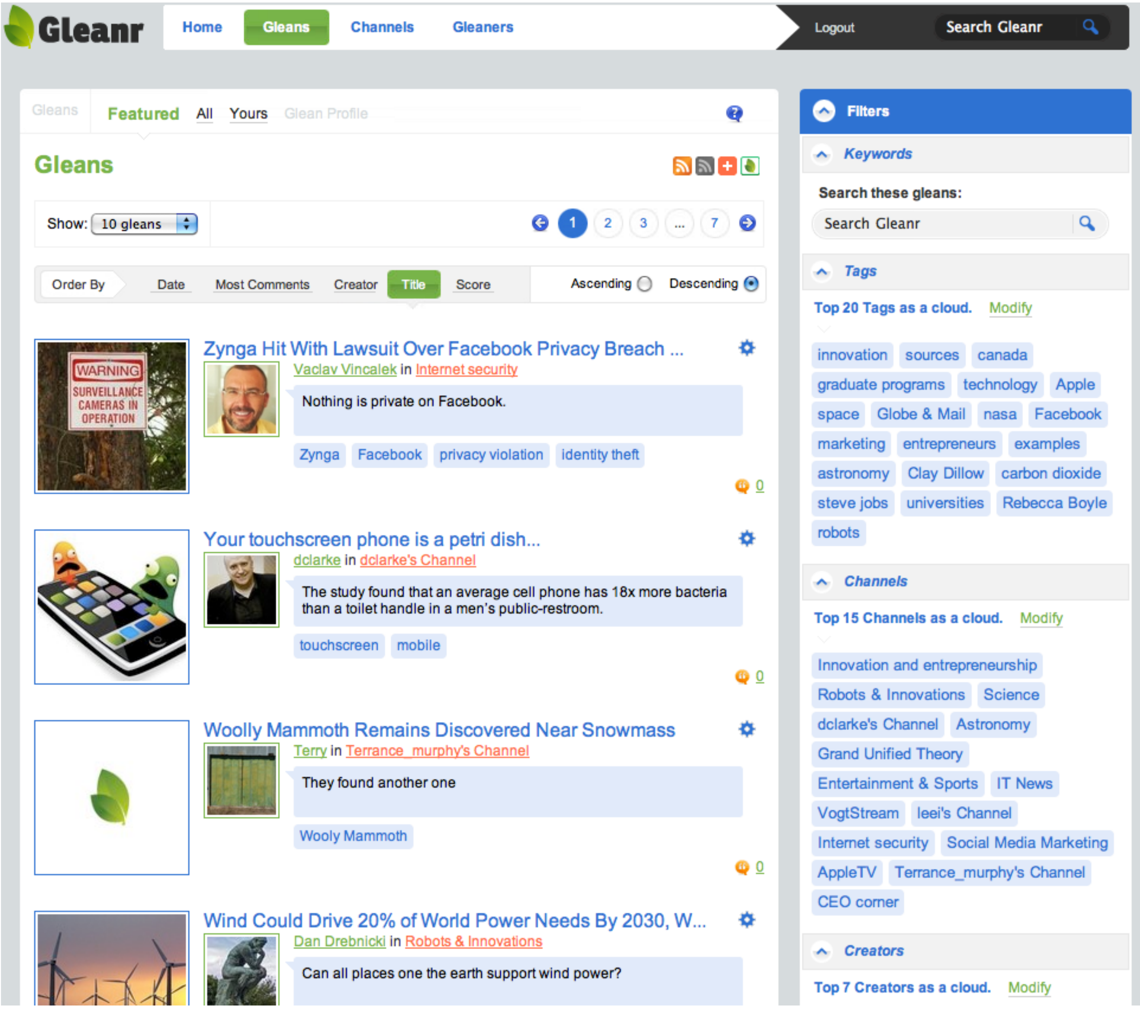

Figure 2. A series of "gleans" in Gleanr

3. THE STUDY

The first public dissemination of Gleanr happened in fall 2009. In order to further promote the software, a handful of acquaintances of the Gleanr design and development team were invited to one-to-one sessions where we introduced the software and it applicability to their daily information management practices as we saw fit for each individual. We also asked each of the attendees to introduce Gleanr to their personal and professional network if they find it useful for them. In total, 10 people accepted our invitation to use Gleanr for

a certain period of time and participate in our study. The individuals' ages ranged from 25 to 40 and they were all well-versed in the use of computers in general and social software systems in particular. While none of the participants were information technology professionals, for all of them use of the Internet and activities such as bookmarking, reading feeds, and publishing online content was part of their professional and/or personal life.

With their permission, we closely tracked and monitored the usage of the tool for this select group over a three-month time period. After that, they were invited for a contextual inquiry in which each individual was asked to fill in a survey questionnaire and participate in a semi-structured interview. The participants' age ranged from 30 to 40 and they came from various technical and non-technical backgrounds. While for some, the use of the tool had become a daily necessity, others had not warmed up to it. This gave us the opportunity to analyze the users' reaction to the tool in different circumstances and to probe for specific success factors and usage barriers in each specific context.

4. QUESTIONS

In order to collect feedback on both benefits and challenges of using Gleanr for our user community, we organized our questions along various dimensions. First, for each of the main functionalities that Gleanr provides (i.e., channels, bookmarklet, RSS feed, broadcast, search, etc.) we asked each of our participants whether they have been using the feature and if not, whether this has been due to the lack of usefulness or ease
of use. Second, we set to find out whether the tool provides enough cues as to how to start a task and its intermediate steps by asking our participants whether they can figure out how to use any of these system

functionalities (i.e., whether it is easy to set up account, create/use channels, feed to LinkedIn and FaceBook, or use the bookmarklet). Next, we moved on to the more advanced features of the system such as privacy management and channel administration; and finally, we discussed the community effect in Gleanr by investigating whether our participants have taken advantage of others' presence in the system (by searching for other tags/channels/people, for example, or subscribing to someone else's channels). We also asked each participant to name the most beneficial feature of Gleanr and whether there are other features that they would like to see added.

5. RESULTS

In the following sections, we present the findings of the research and reflect on the lessons learned from Gleanr's first pilot deployment. The findings have been categorized according to the six dimensions of the Delone and McLean information systems success model [2], including system quality, information quality, usage, individual impact (impact for the user), organizational impact (impact beyond the user), and user satisfaction. While other models exist, the Delone and McLean model is especially appropriate because of the proven interrelationships among (nearly) all dimensions [3], just as our success factors and usage barriers interrelate.

5.1 System Quality: Simplicity

Like many other information systems, the main barrier in the adoption of Gleanr seemed to be lack of simplicity. We noticed that often times the reason behind not using a feature in the system was either the fact that users had not noticed it or that they had found it cumbersome to use. In various occasions, users reported to have stopped using a feature after making frequent mistakes, getting stuck, or seeing some unexpected behavior. This emphasizes the need for making main system functionalities simple, highly visible, and intuitive (i.e., what is the first thing to do upon entering the application?). This is especially important for adoption, since it is highly unlikely that users would be willing to take some mental effort to enter the system before they have been exposed to its benefits.

5.2 Information Quality: Right Balance in the Cost/benefit Equation

One important factor in the design of every social tool is providing the right balance in the cost/benefit equation. Cost is usually defined in terms of initial effort associated with learning or using a tool (whether there is need for training, for example). Benefit, on the other hand, comes from addressing a need or presenting an advantage over other similar tools or alternative methods of performing a task; such as increased speed, better availability, portability, or additional functionality. It is important that such benefit (or a tool's *value proposition*) is clearly defined and communicated to users. Our results indicated that Gleanr has been successful in articulating its value proposition to users. Our participants named a number of benefits in using Gleanr, including control over one's digital presence (e.g., what appears about them in search engines), fast indexing (how quickly Gleans appear in search engine results), ability to manage all contributions and activities that one personally makes in a tool, ease of tracking information of interest, and ease of modification. A major benefit mentioned was the availability of the user-generated social metadata associated with the content (e.g., tags, comments, channels, ratings, etc.), which helped users to assess the relevance of information from various resources, and to arrive upon niches of high relevance and interest to them, thus adding to the overall quality of the information available to them through the tool.

5.3 Usage: Appropriate Functionality to Support the Adoption Model

Gleanr creates a pervasive technical infrastructure that includes people, assets, relationships, and activities as fundamental system components. Moreover, the connection between content, its associated metadata (i.e. tags), users, and their relationships creates opportunities to exploit the "wisdom of the crowd", and deeper analysis of community structure helps identifying trends and experts. However, the "wisdom of the crowd" model works only if the system is successful in securing a critical mass of members who use the system regularly [6]. The choice of adoption strategy (top-down, bottom-up, inside-out, or outside-in [7]) plays an important role in reaching this critical mass. In our case, we believed that the right adoption model for Gleanr would be the bottom-up approach. This model involves identifying key users, who can potentially benefit from using the tool, and then trying to convert these key users into evangelists who can help spread usage (e.g., by encouraging people in their professional and/or social network to start using the tool).

One interesting finding of our study, however, was that usage depends more on how many people *from the personal network of the user* are using Gleanr, as opposed to how many users Gleanr has as a whole. In this regard, the private invitation function in Gleanr (supplemented with a video tour describing Gleanr functionalities and how to start with it) proved to be a suitable tool in improving adoption, as it enabled satisfied users to inform others in their network of their satisfaction and invite them to see a preview. Another interesting finding was that awareness of the activities of one's network had a motivating effect on users to participate more actively in Gleanr. Providing such awareness, however, often presents a trade-off with privacy as users need to be reassured that their data won't be exposed against their will [4]. In that regard, Gleanr's powerful privacy management system proved useful in maintaining users' trust while providing such awareness.

5.4 Individual Impact: Ease of Integration

Another important factor in shaping users' willingness to use Gleanr was ease of integration with other tools and services. When asked how they would define Gleanr after using it for a while, our participants' answers ranged from "a glorified bookmarking tool", to "a personal publishing tool", to "a centralized organization tool", to "a collaborative tool for research", which showed that the many affordances of the tool allow users to tune it to their particular context of use. One consistent aspect of users' experiences, however, was that they all had tried to integrate it with the tools they were currently using for the same purpose, being it a blog (for personal publishing), a wiki (for collaborative research), or CiteULike (for bookmarking). One positive aspect of Gleanr that consistently showed up in users' reports was ease of such integration (e.g., one can write a blog post in Gleanr and automatically feed it to the blogging tool of his choice). Also, the automatic feed from Gleanr to Facebook, Twitter, and LinkedIn proved to be quite popular with users, as it enabled them to use Gleanr as a portal to feed their various Web 2.0 applications.

5.5 Organizational Impact: Creating Incentive for Initial Usage

Generally, users don't want to be trained to use a tool, and they don't want to have to change their behavior in order to be able to embed the tool in their daily activities. Furthermore, a fast Return of Investment (ROI) is often needed to secure their continuous use of a software application. While Gleanr seemed to perform relatively good with regard to the first two cases, one problem seemed to be the fact that users needed to make a considerable initial investment in the tool (by Gleaning content and creating and managing channels) before Gleanr's main value proposition (personal branding) would materialize. This slow ROI (the *differed benefit*) was one of the major complaints users had about Gleanr. Our results indicated that users will not be satisfied with a system that could help some time in the future, but one that is of immediate value for their everyday professional and/or personal lives. As such, providing them with clear evidence of a immediate benefit that will make them better off seemed imperative.

One way to create incentive for initial usage is to pre-populate the application with valuable, relevant content in a simple and accessible format. While this will guarantee that the immediate value of the tool is obvious to users (even before they have used it extensively), there is also need for low cost/risk methods that allow users to test the waters and train behavior. One reason behind users' reluctance to post content in social tools is confidence: users are often hesitant to post because they are not sure of their opinion or how the group will react to it. Providing anonymous and aggregated contribution methods (such as rating and ranking) can help alleviate this problem as these functionalities provide a sense of feedback from community in terms of value/relevance by showing users that their opinions matter while allowing them a non-threatening venue to test group reaction. Providing such anonymous and aggregated contribution methods is part of our future development plans for Gleanr.

Also, as a tool that claims to help users build credibility based on their surfing experience, users expected Gleanr to help them create an audience (i.e., by acting as an information broker) or somehow show their relevance in the area they were trying to identify themselves with (i.e., by facilitating between a user that Gleans about biking and companies that sell stuff related to biking). Implementing an information broker functionality is also part of our future plans.

5.6 User Satisfaction: Usability

While all the factors so far deal with the back-end design and information architecture of the system, the last factor deals with the front-end design and users experience of the tool. This is equally important, as poor user experience can cause the most solid systems to fail. To get an understanding of how users felt about the system (as opposed to what the design team perceived it), we gauged users' feedback with regard to the usability of Gleanr by asking them about their ease of interaction with the system. Users' comments showed that while Gleanr seems to be doing reasonably fine in terms of navigation, visualization, and staging (i.e., novice users can start by simply Gleaning, and then move towards the more advance features such as channeling, privacy management, automatic feed, etc., as they become more advanced), there are some usability problems that need to be addressed. Here we mention a few:

- **Learnability:** Although all of our participants had been able to successfully use Gleanr after the initial introduction, most of them said that they wouldn't have been able to do so if Gleanr was not introduced to them in a one-to-one session. This implies that Gleanr has a steep learning curve that needs to be improved if we want our users to rapidly begin working with the system.

- **Efficiency:** Even after using Gleanr for a while, users claimed to sometimes get confused as to where to look for a certain functionality or do a certain task. This implies that better navigation, search, and help options are needed to enable users (who have already learned the system) to attain a high level of productivity with it.

- **Memorability:** Related to the previous two issues is the issue of memorability: allowing the casual user to return to the system after a period of non-use without having to re-learn everything. Although we didn't particularly test Gleanr for memorability, the two previous issues imply that this might also appear as a problem in the future.

- **Error Rate:** It is important for a tool to ensure low error rate, so that users make fewer and easily rectifiable errors while using the system. Furthermore, catastrophic errors must be prevented. Gleanr didn't fair very well in this regard, as most users reported having continuous problem with channel management and setting feeds.

- **Portability:** Finally, integration across platforms (iPhone, desktop, etc.) was mentioned as a missing desirable functionality.

6. DISCUSSION

Although Gleanr has been designed with use cases beyond just educational, it is not hard to imagine it getting adopted and used as a PLE. In fact, some of our users had been using Gleanr as a personal research assistant; a usage which is very much inline with the goals and purposes of a PLE. As such, our findings, while situated in the general context of social software, are well applicable to PLEs as well. It is important to note, however, that considering the nature of the tool and the focus of our study, the identified adoption factors are rather addressed to the context of social software in general and that specific characteristics of the personal learning environments have not been factored in. It is logical to assume that conducting the same study in a tool specifically designed for eLearning or used for educational purposes might result in a revised set of factors or put emphasis on some factors and less on others.

While the weaknesses of Gleanr (such as complexity and deferred benefit) can be considered as lack of fitness to the environment, its strong features (such as ease of information tracking and powerful control through privacy management) can be identified as characteristics that can ensure (or at least improve the chances of) evolvability. The evolvability of a biological system has been widely studied and shown to be dependent on several properties [8]. Table 1 presents a summary of these properties and their potential equivalent in Gleanr based on the results of our study.

Biological Evolution Factor	Corresponding Gleanr Functionality
self-organization	automated feeds
modularity	channels
gene duplication	new functionality to address new needs (e.g., anonymous and aggregated contribution methods), or existing functionality (e.g., tagging or rating) used by other users or for other purposes
gene robustness	the capability of a function to work in a new situation and still satisfy user's need; e.g., building an information broker functionality on top of the channeling mechanism (building new custom assets on top of robust core assets)
symbiosis	ease of integration with other tools, which enables "cross-fertilization" [5] of information among different web 2.0 platforms

Table 1. Comparing factors in biological and software evolution

7. CONCLUSION

In this paper, we reported on a diagnostic evaluation study on a social software system, Gleanr, to identify its positive as well as negative features and to evaluate its fitness for the purpose. By identifying main areas where users have difficulty with the system, we were able to probe major usability problems, obtain approximate measures for users' effectiveness, efficiency, and satisfaction, and gain an understanding of users' perspective on the tool.

Social software systems are different from other software tools in terms of ubiquity, scale, collision, and exposure. To be successful, a social software system needs to recognize this difference. Based on the results of our subjective assessment, we proposed a set of criteria for the success of social software tools. Although our study was small-scale, the results seem to present a general view of factors that can potentially affect success or demise of a social software tool. We hope that these results can benefit other researchers and practitioners in creating social tools with better chances of mass adoption.

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