

Ecosystem-based Theoretical Models for Learning in Environments of the 21st Century

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Abstract—Members of our modern society are faced with fast and ever-changing political, social, economical, technological and environmental situations. Consequently, it is expected that members of the society keep pace with these variable situations, and be able to adapt their skills and expertise. Thus, modern ICT-based learning approaches are required and E-Learning 2.0 is a promising and interesting approach in this context. Although there is an increasing interest in the E-learning 2.0 topic, there is a lack of concrete and sufficient models. In this paper we explore how the notion of ecosystems and existing ecosystem-based models for learning are applicable for E-learning 2.0 approaches.

Index Terms—ecosystem, Web 2.0, e-learning 2.0, instructional design, learning environment, conceptual model

I. INTRODUCTION

Our society of the 21st century makes great demands on its members in virtually every part of their lives. Members of the society must constantly keep pace with today's changing situations, adapt their skills and expertise with agility, collaborate and compete to provide value to society. It is well documented that our society is characterized by rapid developing and ever-changing political, social, economical, technological and environmental situations.

As a result, modern instructional design, learning goals and processes as well as appropriate learning environments must support the development of the aforementioned expertise and skills. Educational approaches have changed over time from less formal schooling in the agrarian society to "mechanized" knowledge transfer in the industrialization age. From this remedial repetitive learning it has further evolved to today's learning with an understanding to become more independent in the learning process, strengthen meta-cognitive and teamwork skills as well as link knowledge in cultural context to be prepared for lifelong learning. Based on the above, different modern educational strategies have been developed to include aspects such as self-directed learning, collaborative learning, experiential-based learning, actively participating and content creation [5, 19, 43].

Educational approaches have also been influenced by technology but have also increasingly applied technology over the last decades, to include motion pictures, radio, television, computers and other emerging information and communication technologies (ICT). Moreover, children

who grew up with entertainment technologies such as Playstations, Wii, iPods, iTunes, etc; and mobile technologies are more than likely to apply ICT in virtually any situation. This new generation, termed as digital natives or net generation, uses technology as a tool everywhere, and at anytime for any purpose. They are experienced multi-taskers using several media simultaneously for communication, learning and entertainment. In recent years concepts such as social software, collective knowledge creation and mash-ups have become popular as Web 2.0 [42, 43, 51]. E-learning researchers and vendors have adopted these ideas which have become known as E-Learning 2.0 [18]. It is argued that a modern learning environment must support different end-devices, media, sources and services. Teachers and students must have the freedom to choose their preferred tools and learning content within the learning process anywhere and anytime. Moreover, learning must be contextualised and linked to other processes of our daily life [9, 23, 24, 25].

The complexity of modern learning setups of the 21st century require appropriate models and reference architectures (a) to communicate the conception of topical learning from different viewpoints, (b) to identify the multidisciplinary relations of research areas, (c) to assess and classify learning approaches and implementations, (d) to provide domain knowledge for research and development activities.

An attempt to cope with the complexity as mentioned above gives rise to a number of approaches. This includes: (1) learning standardizations such as learning metadata, content aggregation and reuse, learner information, accessibility and runtime environment [35], (2) reference models, architectures and e-frameworks for learning such as the Learning Technology Systems Architecture (LTSA), Personal Learning Environments, ePortfolio for Lifelong Learning, e-Learning Framework Reference Model for Assessment, ePortfolio for Lifelong Learning, and the Reference Model for e-Learning Governance [4, 10, 27, 29], and (3) reference models and architectures which deal with the technology aspects of distributed services for information exchange and knowledge transfer, see examples [20, 36].

Although there exist in variety of approaches as outlined above, it is our belief that the high complexity of the environmental conditions, the need for collaboration and competition, and the high dynamic of changing relations between members of the learning community, sources and services are not sufficiently covered. These characteristics of modern learning settings, comparable

with the situation in biotic (*living*) ecosystems, have motivated us to start research for a holistic ecosystem-based model for learning and e-learning [9].

In this paper we explore how the notion of ecosystems and how existing ecosystem-based models for learning and e-learning are applicable for such modern learning settings. To this end the remainder of the paper is organized as follows: Section 2 discusses aspects of learning in our techno-competence-based 21st century and identifies most important aspects which need to be considered. An introduction to the ecosystem conception and application domains is outlined in Section 3, followed by ecosystem-based theoretical models for learning and e-learning in Section 4. Findings and future work complements are found in Section 5.

II. ASPECTS OF LEARNING IN THE TECHNO-COMPETENCE-BASED 21ST CENTURY

In the first decade of the 21st century a paradigm shift is progressing from a knowledge society to a competent society [37]. In a globalized and technology-driven world, our society is faced with ever-changing and fast developing situations in every aspect of their life. The amount of produced data has increased dramatically [33]. The use and application ICT has contributed to the rapidly changing global economic and financial situations [44, 48]. Knowledge doubles between five and ten years depending on the knowledge domain and it is estimated by the year 2020 knowledge may double within months [12, 50]. The evolution of ICT continuously increases and product life cycles are consciously getting shorter [1], and there is a growing and ever-changing supply of business and services especially in e-services and e-business [15]. Society expects its members to keep pace with these developments, adopt knowledge adequately and develop appropriate skills and competencies. In particular soft-skills have become increasingly important. Soft-skills are vital for members to think and learn, to communicate and collaborate without language and cultural barrier, to be self-initiating and self-organized, in order to adapt to the complex and ever changing environment [5, 12, 24, 39, 53]. All individual members, formal or informal groups such as companies, governmental and non-governmental organizations, and even virtual communities must keep pace with these developments [8, 39, 46]. It is expected that individuals as well as diverse groups must be able to adapt in their roles in these environment to compete and collaborate in order to provide value for society and survive in their roles [12, 31, 50, 53, 55]. Therefore, individuals and communities must develop a great variety of hard and soft skills. Modern learning processes and environments must support this situation.

Unlike the past where education mainly concentrated in the first ages of human life through formal education and specific training in business life, in an uncertain world, learning becomes a day-by-day routine over the life cycle. Consequently, new forms and channels in the learning process are needed. [39] It is expected that members of our society will develop skills beyond simple facts and domain subjects. They must be able to build meta-cognition skills to learn on their own, to search continuously for more creative solutions, and to collaborate with peers and interact with knowledge services [5, 8, 12]. Instructional design and curricula in formal education as well as educational and training

settings in business environment must be open and flexible to provide room for these perspectives [10, 12, 39, 41]. Out of the myriad of suggestion and requirements in literature, a selection of interesting aspects is outlined as follows.

Focusing on the learning process itself, Burra in [8] suggest an approach that is contextual and timely in the face of changing learner requirements. Bransford, Brown, and Cocking in [5] support these requirements and complement it with social and cultural aspects to be considered in the learning process. They further outline that modern learning environments must consider learning community aspects as well as learner-centred, knowledge-centred and assessment-centred aspects. Ismail in 2001 [28] and Gütl in 2007 [24] advocate as many others that the learning process must support individual learner profiles which include task and role-based aspects, interests, knowledge state, short-term learning objectives and long-term career goals. Shrivastava in 1998 [46] emphasizes another problem in traditional formal education which is the artificial scheduled 60 or 90-minute learning sessions over a semester and that applied learning content is often too static and outdated. He suggested a more natural 'continual anytime anywhere learning approach' where students can learn when they are ready to learn and have need for the knowledge which is continually updating through knowledge instruments and networks. But not only processing and acquiring knowledge is a key to a modern learning approach, but also collaboration and community-based practice for knowledge and skills development are important success factors [8, 47]. In order to cope with the above complex situation, various teaching and learning strategies were developed, such as peer teaching, experiential-based learning, ad hoc learning, learner-centred and self-motivated learning [30, 39, 47]. Wilkinson in 2002 [54] suggested a problem-based learning approach which gives the motivation to search for relevant information to solve the problems, and based on that develop knowledge and competencies. The author also suggested taking multiple opinions and sources into account which enabled the students to broaden their view to the problem and related subject domains.

From the organization point of view, learning must be seen as integrated activities which take place over the entire life cycle of the individuals in virtually any part of life, such as educational organizations, business and leisure time. In this context, Wilkinson clearly points out that "[...] *working backwards from the desired learning outcome, the learning delivery system needs to provide access to all relevant resources. These resources can include: a knowledge base, a science, a particular body of knowledge, or a human resource such as a mentor, professor or subject matter expert.*" [54] Siemens in 2003 [47] further call for informal instead of structured learning; therefore the environment should be flexible enough which allows learning and discussions activities according to specific needs. Furthermore, learning is not restricted to one learner or a stable pre-defined group. The network of learning agents and sources dynamically changes according to situations and context; it may include individuals, intelligent agents (based on artificial intelligence), communities and organizations such as education institutions, R&D institutions, business and industry, digital libraries, and web resources [13, 17, 39].

Learning is a continuous process which impacts and is impacted by other areas of work and life. As mentioned above, formal education and training programs are artificial constructs in terms of scheduled learning units, but also most settings do not allow following up new aspects of this topic or even accessing the course content after the completion of the course. To overcome this situation, Siemens in 2003 calls for more improved and flexible solution [47]. Because of this dynamic and openness, further aspects become important, such as digital rights management [11], trust building [26, 47] and security and privacy [32].

By focusing on student characteristics, the traditional image of students has significantly changed. According to Witherspoon in 2006 [55], only 20% fit into the traditional image of an 18-22 student taken courses fulltime. The majority is comprised of part time students as well as employees and citizens, even from other regions and countries, who selectively enrol in courses and participate in programs. Therefore it is important (1) to concentrate on outreach and access to get potential students involved, (2) to make courses and programs comparable and transferable, and (3) to make it easier for students to transfer their records from institution to institution. [55] Another interesting aspects is that the roles of content creators and content consumer or teachers and students are increasingly blur which is caused by the development and widely adoption of modern ICT based on social software and e-learning 2.0 [3, 43]. Because of the need of life-long learning and the age distribution of today's students, a great variety of generational differences must be taken into account. AETC in 2008 distinguishes four groups according to their year of birth and assign characteristics to them [2]: (1) *Baby Boomer I* (1946 to 1954; experimental, individualism, free spirited, social cause oriented), (2) *Baby Boomer II* (1955 to 1964; less optimistic, distrust of government, general cynicism and belongs to the groups of digital immigrants), (3) *Generation X* (1965 to 1979; quest for emotional security, independent, informality, entrepreneurial and belongs also to the groups of digital immigrants), (4) *Millennial or Generation Y* (1980 to 2001; quest for physical security and safety, heightened fears, acceptance of change, technically-savvy, environmental issues and belongs to the group of digital natives). These diverse groups of learners require special attention in the learning process and technology in the learning environment must support the different needs; and range from preventing complexity, providing guidance and help but also enable the groups, especially the digital natives the tools of their choice [47, 51].

This complex situation and requirements outlined so far project challenging issues and expectations in the technological dimension. Because of learning is integrated in other processes, learning tools must also linked to other systems and support to identify pre-existing sources (content, services, individual and groups) [28, 40]. But the expectations from technology are more than that, as Burra in 2002 [8] clearly outlines that “*instead of adapting and delivering content to learners per technological limitations, technology is being leveraged to ensure a comprehensive and natural learning process.*” Another important dimension is also the support of diverse end clients to enable learning virtually everywhere and everywhere, such as traditional personal computers,

mobile devices, home entertainment devices, and their convergence [24]. Learners must have the control – at least to some extends – over the learning process and learning tools. If the learning process and the learning environment are too restrictive, students tend to go ‘underground’ and select available tools outside the organizational borders [54].

As a result of this section, demands for learning in the 21st century are manifold and a sound learning environment is very complex in term of pedagogical, cognitive, social, organizational and technological aspects as well as influenced by ever-changing environmental situations. Based on these findings, we want to explore if the ecosystem notion and its application for e-learning-based are applicable to provide appropriate models and reference architectures for such complex learning settings.

III. INTRODUCTION INTO ECOSYSTEM NOTION AND APPLICATION DOMAINS

The basic concept of ecosystem was first introduced by a British ecologist A.G. Tansley. He defined an ecosystem in 1935 as a “*community or assemblage and its associated physical environment in a specific place*” [49]. However, Tansley's initial definition does not explicitly mentioned interrelation and interaction. The term ‘system’, borrowed from the physics domain by Tansley, implicitly highlights the interaction between the living and non-living components. Today the definition according to the Encyclopaedia Britannica defined an ecosystem as a “*complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space.*”

As a fundamental example, a natural ecosystem is a biological community of interacting organisms and their physical environment [22]. The interactions between the living and non-living components within an ecosystem may include a high level of complexity and it may also include a nested hierarchical structure. In addition, the ecosystem can be of any size as long as a symbiotic relationship and interactions exist between organism and the physical environment [38].

The power of the generic definition of ecosystem is its applicability to any system, and incorporating the interactions between living and non-living components of an ecosystem. To be more specific, a model indicating the adaptation of ecosystem is required for a particular application domain. Some of the features of a concrete model are defined by external aspects, and other features emerge from within the system. In order to describe a particular instance of a model, the following characteristics have to be specified: (1) the living and non-living components as well as proper level of aggregation, (2) the temporal extent and the temporal and spatial scale, (3) the physical boundaries of the system, (4) the description of type and extent of relations and interaction between identified components, and (5) constraints on system behaviors [38].

Given these insights, it is obvious that the model of the ecosystem strongly emphasizes a holistic approach highlighting the significance of each component, their behaviours, relationship and interactions, as well as the environmental borders in order to create a new system or examine an existing system, or form an effective and successful system. Pickett and Cadenasso assert in 2002

that ecosystems can be widely applied to humans and human-generated processes and structures [38].

It is this fundamental ecological concept covered by the ecosystem and its applicability to various application domains as well as the exciting and interesting holistic approach that led us to transform the idea of the ecosystem in the learning domain. The following section explores the applicability of the ecosystem approach for E-learning 2.0.

IV. ECOSYSTEM-BASED THEORETICAL MODELS FOR LEARNING

A. Selection of Compact Models

Dimitrov in 2001 [17] builds on the basic definition of the ecology as the study of *“the web of dynamic interactions of the living creatures, including humans, and their environment - natural and artificial (human-made).”* Linked to this definition, learning is a process which *“is vital for sustaining the integrity of this web and hence for sustaining the life and its unfolding.”* Based on this, learning ecology *“focuses on factors and conditions facilitating the process of learning and searches for ways to increase its efficiency, in the sense of opening new possibilities for realization of the self-organizing impetus of the living entities, at any level of the web of interactions.”* These definitions form a notion which takes into account the dynamic interaction of humans and intelligent machines in an ever-changing environment and their learning process how to better cope with the changes in this environment.

Cowley et al. in 2002 [14] do not give a definition of an ecosystem for e-learning but they outline components of the ecosystem. The authors address multiple aspects of a complex learning setting by the following ecosystem components: (1) the *learners and the teacher* as the most important user groups in the learning process, (2) the *content* for the learning process, (3) the *organization* in which the learning take place, (4) the *environment* students need for the learning process, (5) *technology* that supports the learning process, (6) *skills* to perform in the ecosystem (such as technical skills, subject matter skills and study skills), and (7) *support* to help within the system if they are facing problems.

Another interesting notion is stated by Siemens in 2003 [47] where a learning ecosystem orchestrates a variety of learning approaches given by the varied characteristics of learning processes. Here, the e-learning ecosystem is seen as an environment which is *“consistent with (not antagonistic to) how learners learn.”* The depicted set of aspects characterizing a learning ecology is based on [7] and addresses an open, dynamic and independent system, which may be fragile, partially self organizing and adaptive. Furthermore it is characterized by a collection of overlapping communities of interest, cross pollinating with each other and constantly evolving. This approach focuses mainly on the learning process dimension and takes also aspects of learners' characteristics and the dynamic of the environment into account.

Unlike the generic viewpoint of learning settings above, Lavrin and Zelko in 2005 [31] proposed a digital ecosystem for small and medium enterprises for knowledge sharing. The two authors built on the notion of a business ecosystem and transposed the conception in the

digital world. A digital ecosystem is seen by them as *“an ‘evolutionary self-organising system aimed at creating a software environment for networked organisations’ that supports the development of open and adaptive technologies and evolutionary business models.”* This proposed model focuses mainly on the technological infrastructure and services.

Pirie in 2004 [40] also focuses in his paper on learning in business settings. He defines an ecosystem as an *“an ecological community that, together with its environment, functions as a unit”*, and leaves out important aspects of an ecosystem. Based on this simple definition the author describes an e-learning ecosystem as *“the learning community, together with the enterprise, united by a learning management system (LMS).”*

Witherspoon in 2006 [54] focused in his work on an academic ecosystem and identifies for such settings three main elements, namely (1) the *student body*, (2) *technology, teaching and learning*, and (3) *institutions of higher education*. The outlined elements address aspects of the learning community, the learning process, organizational and technology issues.

B. Knowledge Ecosystem from Shrivastava

Shrivastava in 1998 [46] was motivated by the fact that organizations have to cope with expending information technology and knowledge work. Based on that he identified the need for a framework to combine human intellectual capital and digital technology processes, and he proposed knowledge ecology conception for business education and training. The knowledge ecosystem is seen to be like a natural ecosystem in terms of interaction and exchange within units in the system, with their environment and even with other ecosystems. Such systems can be integrated at different layers and levels to form more complex systems. The author furthermore outlines that knowledge ecosystems consist *“of interlinked knowledge resources, databases, human experts, and artificial knowledge agents that collectively provide an online knowledge for anywhere anytime performance of organizational tasks.”* Organisational tasks in this context include work performance, learning activities and even both may blur into a continuous learning-working process.

Key elements of such a type of ecosystems includes: (1) core technologies for both the infrastructure and substantive knowledge of the industry, (2) critical interdependencies in a complex social technology network of individuals, systems and procedures inside and outside the organization, (3) knowledge engines and agents which create knowledge, and (4) performative actions to convert knowledge in economic value include cognitive actions (such as deciding and learning) and physical actions. Shrivastava's components of a knowledge ecosystem for learning and training covers aspects which can mainly linked to technological, learning community and organizational dimensions.

C. E-Learning Ecosystem from Wilkinson

The learning ecosystem form Wilkinson in 2002 [54] is motivated by supporting a learning approach where learning and work are *“seamlessly and inextricably linked”*. Further important aspects are the access to virtually all relevant information and the need of an enhanced infrastructure which enables authentic learning. The elements and their relationships of Wilkinson's

comprehensive and cohesive learning ecosystem are depicted in Figure 1. It includes (1) a content taxonomy, (2) learning content management system, (3) learning management system, (4) learning content (such as learning object repository and external knowledge access), (5) electronic performance support, (6) workflow management and integration system, (7) simulation and game engine, (8) mentoring and support, (9) collaboration systems (such as discussion and conference tools), and (10) assessment and evaluation system. Although a broad view of the learning process is given by the ecosystem model and a number of important elements have been identified, most attention is given by the author to reusable learning objects and the content taxonomy. This model mainly focused on aspects of content, learning process and technological dimensions.

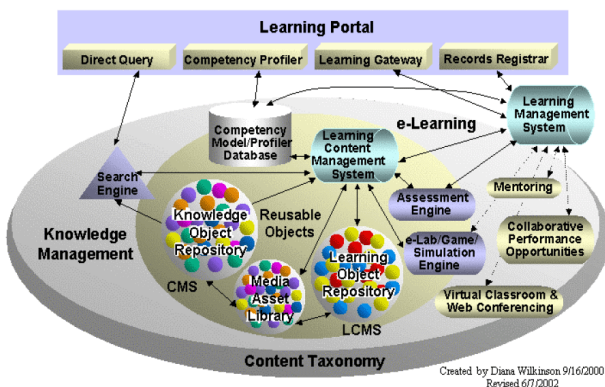


Figure 1. E-Learning ecosystem from [54]

D. E-Learning Ecosystem from Brodo and Extended Version by Uden et al.

Because of the fact that e-learning industry is constantly changing, Brodo in 2006 [6] was motivated to provide a model how organizations should apply e-learning and new methods to reduce effort associated with traditional training. He defines the e-learning ecosystem as “the term used to describe all the components required to implement an eLearning solution.” The components of the ecosystem are further categorized into three classes: the content providers, the consultants and the infrastructure; see also Figure 2.

The *content providers* offer learning content for learning solutions for different learning settings such as classroom-based, online and blended learning. Brodo furthermore identifies three groups of content providers which are utilized in combination in practical learning settings: (1) branded content provider, (2) commodity content providers, and (3) custom content providers.

The diverse groups of *consultants* help to develop and implement the learning processes and their technological support. Within this model the group of consultants comprise (1) strategy consultants who focus on the definition of new business strategies and related learning activities, (2) compensation consultants who take attention on employees’ motivation to achieve business goals, (3) information technology consultants who support to setup the infrastructure required, and (4) implementation consultants who bring in their expertise to launch and keep running new systems and strategies.

Brodo in [6] defines his last component, *the infrastructure*, as to be “the ‘plumbing’ for the management, delivery and tracking of e-learning.” Although this broad definition of infrastructure was given, only three classes of this component are outlined in the model: (1) the learning content management system (LCMS) enables to efficiently manage the process of training and management, (2) the content delivery system which provides the internet-based learning infrastructure for the learning, and (3) tools are seen in this model to be used to transfer “intellectual property into a learning content”.

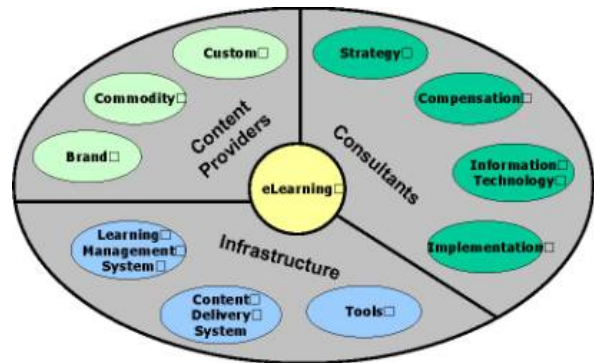


Figure 2. E-Learning Ecosystem model from [6]

Uden, Wangsa and Damiani in 2007 [52] built on the aforementioned model from Brodo and propose an extended version based on [16]. Orthogonally to Brodo’s three components, three different layers have added: (1) *the ecosystem infrastructure* includes basic services components, generic integrated solutions and infrastructure components, (2) *sector-specific systems* comprises services, solutions and components tailored for a specific sector, and (3) *local systems* addresses local implementations of the sector-specific systems. Furthermore, the authors outline an approach how to develop e-learning ecosystems. The steps include (1) identify needs of organization, (2) constructing the technology solution: selecting the right LMS, (3) pedagogical design, (4) content in an ecosystem, and (5) continual improvement of applications and infrastructure.

Brodo’s original model addressed mostly aspects of the content and technological dimension, and the model focused on organizational learning with less freedom for learners selecting tools of their choice. The extension of Uden et al. mainly focused on technology aspects and increases the flexibility of learning environments to be composed of distributed services.

E. E-Learning Ecosystem from Ismail and Derived Model from Maneschijn

Ismail in 2001 [28] does not explicitly refer to any theoretical background but outlines that basic components constitute an e-learning ecosystem. The framework outlined in Figure 3 is based on the Learning Technologies Systems Architecture [27] and covers mainly the dimensions of pedagogical development and system integration. The author further derives from the model the most important components which are management of learning, learning content design system, learning content management and learning support system.

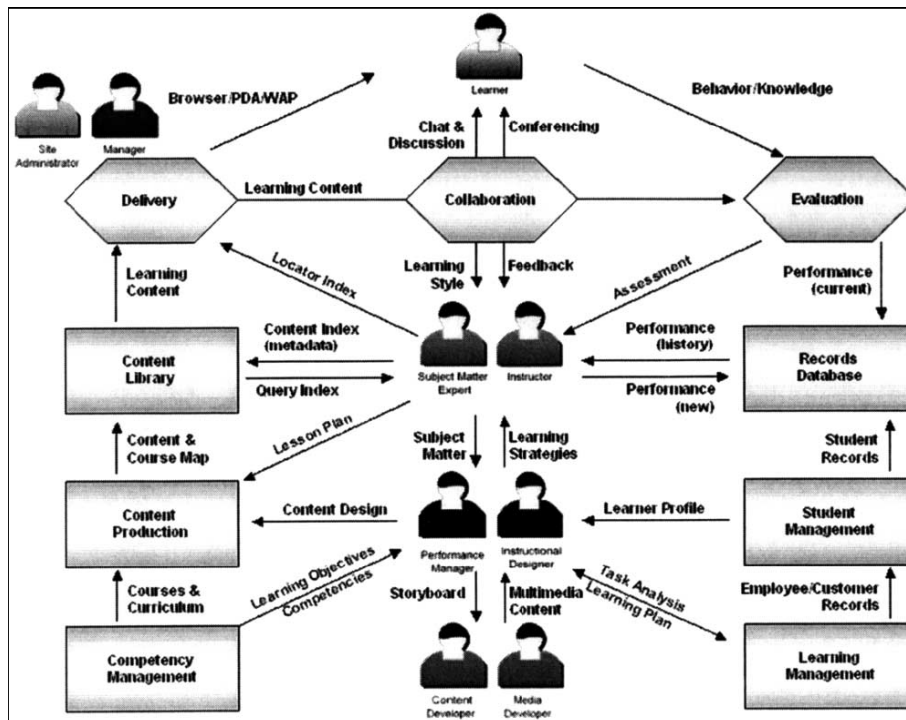


Figure 3. E-learning system framework from [28]

Based on that, Maneschijn in 2005 [34] adopted the framework and defined an ecosystem model which comprises three components (see also Figure 4): the learning design system, the learning content management system and the learning support system. Maneschijn’s model mainly focuses on a technological viewpoint.

E c o s y s t e m	LDS	Competency Management Tool
		Project Management Tool
		Instruction Design Tool
	LCMS	Delivery Engine
		Catalog
		Object Authoring Tool
	LSS	Content Assembly Tool
		Page Authoring Tool
		Collaboration Tool

Figure 4. E-Learning ecosystem from [34] adapted from the framework from [28]

F. ELES Model from Chang and Gütl

Another approach for modern learning settings has been introduced by Chang and Gütl in 2007 which captures stakeholders as well as artifacts and resources [9]. This approach is based on the original notion of ecosystem as outlined in the previous section. In a generalized view an ecosystem is classified by living and non-living components and all their interrelationships in specified physical boundaries. Transforming that to the learning domain, Chang and Gütl proposed the definition of *learning ecosystem (LES)*. LES consists of the stakeholders incorporating the whole chain of the learning process and the learning utilities, the learning environment, within specific boundaries, which the authors call learning environmental borders.

Given the abstract definition as stated above, a first generic model for learning situations is outlined as follows, see also Figure 5. As the biotic or living units in the ecosystem the *learning communities and other stakeholders* such as teachers, tutors, content providers, instructional designers and pedagogical experts, form the living parts of the learning ecosystem. The *learning utilities* comparable to the abiotic or non-living units (or the *learning environment* comparable to the physical environment) represent the non-living parts, which include the learning media (content and pedagogical aspects), technology, and tools applied in traditional teaching methods. The *learning environmental boundaries*, an analogy to the specified physical boundaries of the ecosystem defines the physical and logical borders of the learning system. That is one of the system’s characteristics, which are in common specified as the *learning ecosystem conditions*. These conditions are determined by external and internal influences, such as evolution of knowledge, educational goals, learning tasks, cultural and sociological aspects, and expectations by society, private industry and business organizations, the government, public service and not-for-profit organizations.

The main interests in the learning domain are relationships and interactions related to the information flow as well as knowledge transfer and transformation. In light of this, some conclusions are identified. Like a biological ecosystem, in a learning ecosystem, individuals can form groups spontaneously and can interact with each other or with learning utilities at the individual or group level. They also can perform, change or adapt specific behaviors in order to contribute to or perturb to the success of the learning ecosystem. Changes in the learning ecosystem conditions influence the “behaviour” of the system and its components. To be successful and to be valuable for the system, each individual and group must

adapt to the environmental conditions to find their niches. In order to fit them all together, proper learning utilities must also be available.

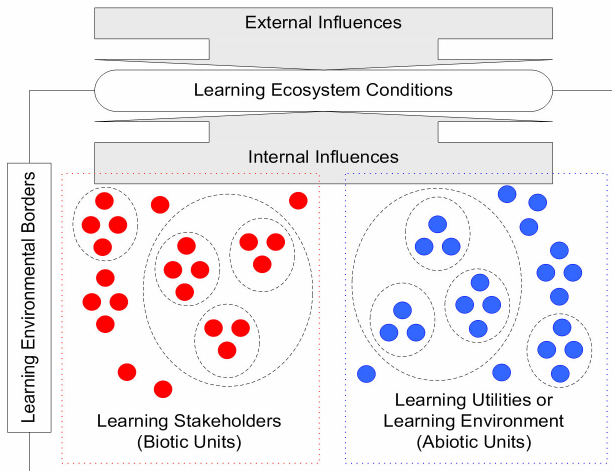


Figure 5. Simplified representation for the learning ecosystem (LES) from [9].

The authors also emphasize that the generic view of the learning ecosystem can be applied to any learning situation, such as traditional face-to-face teaching in classrooms or e-learning in business environments. This is to assert that in any learning situation biotic and abiotic components or cluster of components, their relationships and interactions together with the ecosystem’s conditions have to be considered. Furthermore, the biotic and abiotic components as well as the learning environmental borders and the other conditions of the learning ecosystem are in principle dynamic. This generic view helps to get a better picture about a specific learning situation, and allows educators and practitioners to achieve a more holistic approach for the development of more effective learning.

By restricting the system’s conditions of the proposed learning ecosystem to the e-learning domain it can be constricted to an *e-learning ecosystem (ELES)*. This allows educators and practitioners to identify and examine (a) the specifics of the learning communities and other

stakeholders, (b) the more specific learning utilities, and (c) the more restricted learning ecosystem conditions.

G. Ecological Model of Learning and Teaching from Frielick

Unlike the models outlined so far, Frielick in 2004 [21] exclusively focused on the learning process. He proposed an ecosystemic approach for teaching and learning which – as the author claim – goes behind the constructivistic approach and moves towards the enactivistic approach. The idea is based on the notion of ecological epistemology where the individual mind is just a part of a larger interconnected web of mental processes. Based on that the key idea is that the teaching and learning process is a “ecosystemic process of transforming information into knowledge, in which teacher, subject and student relationships are embedded or situated in a context where complex interacting influences shape the quality of learning outcomes.” Consequently, the ecological model outlined in Figure 6 focuses on the learning and teaching activities on different levels (on the inter- and intra-personal level, on department and on institutional level). The model also addresses the different tasks in the learning process (course design, teaching mode, assessment and evaluation) and takes into account teaching objectives, pedagogical strategies, learning methods and learners’ preferences.

H. E-Learning Ecosystem from Sedita

The proposed framework first published in Sedita in 2003 [45] aims to understand the dynamics of the learning process of modern learning settings at the beginning of the 21st century. The motivation for this framework was given by an interest on knowledge transfer and learning in companies. In particular the innovation process based on this knowledge flow was seen as an ecology process. Although the notion of ecology process has been used, no theoretical background has been provided in this initial paper. Pilotti and Sedita in 2005 [39] explicitly broaden their viewing to learning ecology in a later work about this framework.

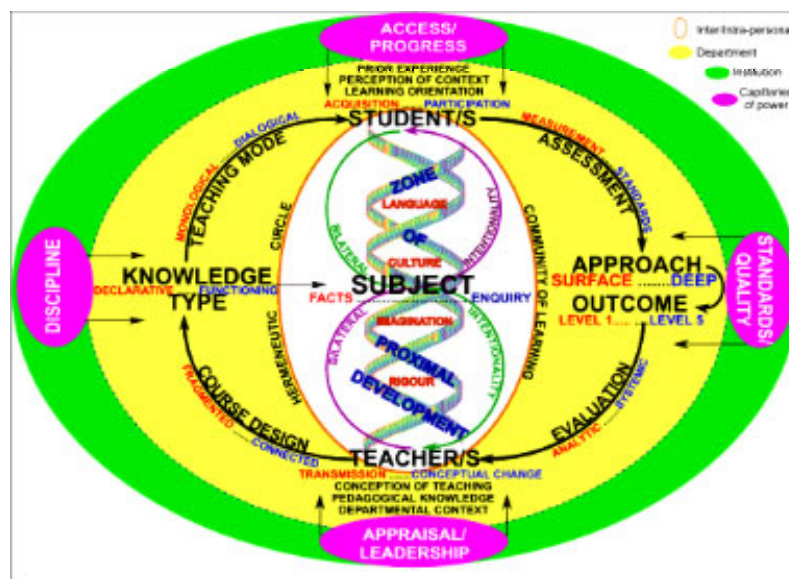


Figure 6. Ecological model of learning and teaching from [21]

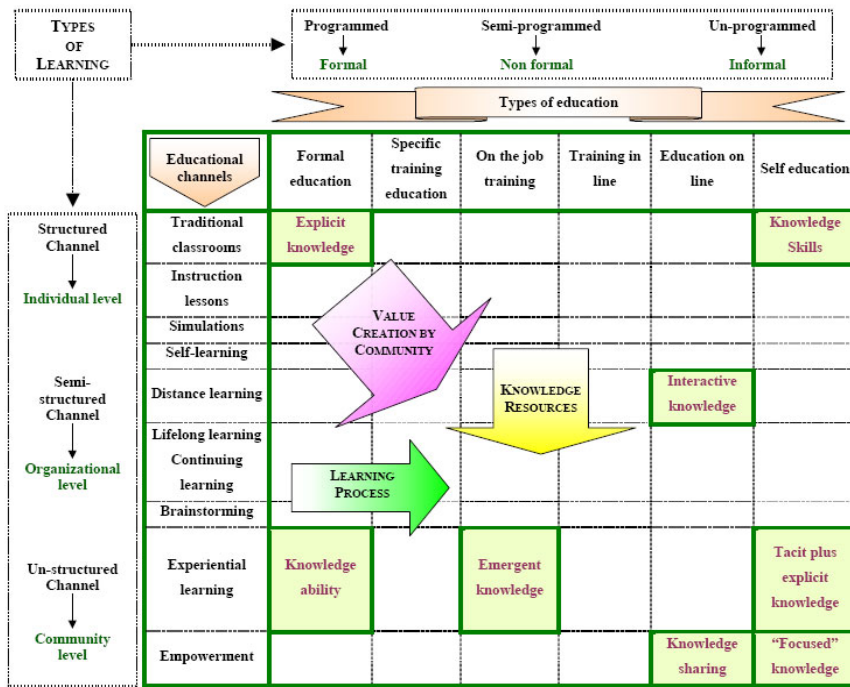


Figure 7. Extended framework depicting the relationships between types of learning, knowledge transfer and channels of education (taken from [45]).

The identified requirements addressed multiple dimensions of modern learning processes, such as different forms of learning on individual and group level, the need for interacting in evolutionary contexts, dynamically linking individuals to other individuals and content, and the need for permanent education in intra-firms, inter-firms and trans-national educational systems. Although these broad requirements have been identified, the framework is yet very focused on four aspects of a learning ecology (see Figure 7): (1) types of learning, (2) agents involved, (3) types of education, and (4) channels of education.

1. Digital Rights Management Ecosystem for Educational Communities from Collier et al.

Collier, Piccariello and Robson in 2004 [11] focused on a topic which is becoming increasingly important in complex learning environments. They provide a model for digital rights management for modern educational settings where a huge amount of learning content from diverse sources, partly collaboratively created, need to be handled. The authors argue that the management of intellectual property rights cannot be managed by ad hoc or proprietary methods. Thus they proposed a digital rights management ecosystem model as depicted in Figure 8. The model outlines a set of groups, applications and services involved in the process as well as intelligent property right aspects are linked to them.

The model includes six components: (1) the *rights management environment* which describes the logical borders and determines the context. This environment is defined by law, policy, practice, market mechanism, organizations, roles, and community expectations. (2) *Actors* subsume people and organizations to whom are rights applied. The key actors include authors, publishes, librarians, repository manager, faculty and students. (3)

Content life cycle includes the processes of creation, distribution, acquisition and use of content. Digital rights management is seen as integrative part in these processes in content management. (4) *Tools and applications* address software which support the content life cycle, and consequently is also affected by the rights management. It comprises authoring tools, content repositories, learning management and delivery systems, and personal computing environments. (5) The rights management processes themselves are organized in the model into four parts: defining rights, distributing and acquiring rights, enforcing rights and tracking usage. Finally, (6) *standards and services* are seen in the model as the component which provides the technological context of digital rights management. This component of the ecosystem is typically strongly linked to other infrastructure of organizations.

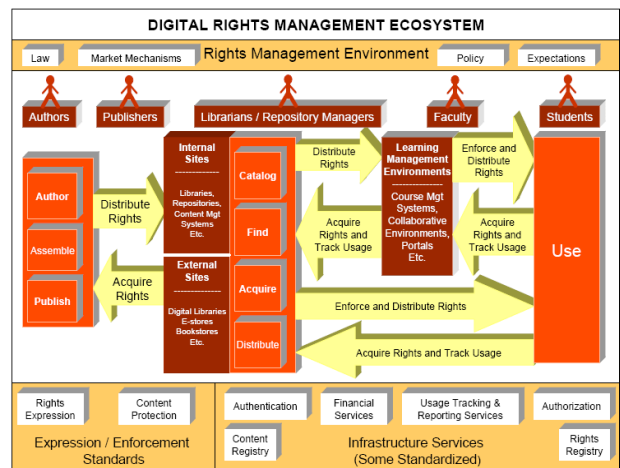


Figure 8. Digital Rights Management Ecosystem for educational community from [11]

V. CONCLUSIONS AND FUTURE WORK

In this paper we have shown that learning must be seen as integrated activities which take place over the entire life cycle of the individuals in virtually every part of life. Learning is not restricted to one learner or a stable pre-defined group. The network of learning agents and sources dynamically changes according to situations and context; it may include individuals, computer-based agents, communities and organizations. Furthermore, not only processing and acquiring knowledge is a key to a modern learning approach, but also content creation, collaboration and community-based practice for knowledge and skills development are important success factors. Consequently, the learning environment must be flexible enough to support the above mentioned situation.

In addition, we have outlined that ICT-based learning environments have analogously matured from content-centered, centralized and more static learning systems of the e-learning 1.0 era to enhanced, people-centric approaches which have become popular as e-learning 2.0. Characteristics includes blurring roles of teachers and students, the collaborative nature of learning, transfer of pre-existing knowledge to recipients, strong focus on content sharing, syndication, reuse and re-purposing, adaptation as well as personalization. The most important dimensions of an e-learning 2.0 environment which need to be considered are (1) the learning content, (2) the learning process, (3) the learning community, (4) the organizational aspects, and (5) the technological aspects. Although e-learning is becoming increasingly popular, to our knowledge no sufficient concepts, models and architectures for researching and developing e-learning 2.0 applications are available so far.

Furthermore, we have explored and shown that the notion of ecosystem which is based on a fundamental ecological concept is applicable to describe and model techno-social systems in various application domains. The idea of the ecosystem is also an exciting and interesting holistic approach which can be applied in the learning domain. A selection of ecosystem-based models for learning situations and application has shown that each of the models covers partly the above mentioned dimension of the learning environment but none of the models addresses sufficiently all dimensions.

In order to better support research, development and evaluation of e-learning 2.0 applications and environments, we will work on a framework which combines and extends existing ecosystem-based models and will provide guidelines of the aspects will be covered by specific models and how to apply them.

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