Learning Network Assisted by Means of Symbolic Computation

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1. Introduction

Background of this work is summarized in (Miralles et al., 2004) and (Marín et al., 2008), where Network Learning (NL) and Learning Network (LN) are described. Their differences are also introduced in such work. However, despite of the need of a learning model from a pedagogical point of view, this pays more attention in the point of view of Computational Science. This is due to the main knowledge area where the work is framed. In (Downes, 2004) are described learning elements, which are lacked in cited work. That paper contains the basic principles and useful elements to develop a model of network learning. In this chapter, we propose complete the open area in previous works.

Under these assumptions, the principal goal of this chapter is to introduce a model for the teaching assisted by network in the framework of connectivism as a learning theory in the digital age. Our model uses a Learning Network-Assisted by using symbolic computation through the web technology. We also present some guidelines in order to develop these web applications. Moreover, a set of paradigmatic examples are implemented by means of this model. Particularly, we show some selected examples that they require that teachers of different subjects to interact amongst them. These applications were based on examples specifically choose in order to illustrate how to increase the transversal character amongst different teaching subjects in Industrial Engineering in the context of ECTS. These examples described here emphasize the web technologies as a well-suited for the learning of scientific and technological subjects. The key idea of these activities, in the context of connective knowledge paradigm, is the use of symbolic computation like a link both among teachers and between students and different matters, and not only as a computational tool.

This chapter is organized as follows. First of all, Section 2 presents a needed criticism of analogical learning theories. Complex networks and connectivism are described in Section 3. Network Learning (NL) and Learning Network (LN) are also described. In Section 4, the AALN is presented and Computer Algebra Systems are introduced. webMathematica technology is discussed in Section 5. This is a useful web technology for support a LN based on symbolic computation. An example of LN based on symbolic computation is described in Section 6. Finally, the conclusions are outlined in Section 7.

2. The Need for Criticism in the Context of the Theories of Analogical Learning

This section will present the arguments of the developers of the connectivism's theory, compared to classical theories of learning in the context of the digital age. Learning theories have two chief values according to (Hill, 2002). One is in providing us with vocabulary and a conceptual framework for interpreting the examples of learning that we observe. The other is in suggesting where to look for solutions to practical problems. The theories do not give us solutions, but they do direct our attention to those variables that are crucial in finding solutions.

There are three main categories or philosophical frameworks under which learning theories fall: behaviorism, cognitivism, and constructivism. Behaviorism focuses only on the objectively observable aspects of learning. Cognitive theories look beyond behaviour to explain brain-based learning. And constructivism views learning as a process in which the learner actively constructs or builds new ideas or concepts. These theories make up the different educational environments, which we usually have a certain familiarity. We would classify these theories as analogics, because they deal about constructions of learning developed in an era where teaching and learning processes does not interact with the technological development of the digital society, and where, therefore, any methodology learning from either of these epistemologies, was implemented under an analogic support.

Over the last twenty years, technology has reorganized how we live, how we communicate, and how we learn. Learning needs and theories that describe learning principles and processes, should be reflective of underlying social environments (Vaill, 1996) emphasizes that: "…learning must be a way of being – an ongoing set of attitudes and actions by individuals and groups that they employ to try to keep abreast of the surprising, novel, messy, obtrusive, recurring events…"

One might consider that the most relevant results from the interaction between teaching and learning processes and the revolution of the digital information, is that the half-life of knowledge has been shortened by at least an order of magnitude, only in the last twenty years. Knowledge grows exponentially, life in many fields of knowledge are now measured in months and years. As a result of the interaction-learning digital revolution, we can highlight the following current trends in learning:

- Many learners will move into a variety of different, possibly unrelated fields over the course of their lifetime.
- Informal learning is a significant aspect of our learning experience. Formal education no longer comprises the majority of our learning. Learning now occurs in a variety of ways – through communities of practice, personal networks, and through completion of work-related tasks.
- Learning is a continual process, lasting for a lifetime. Learning and work related activities are no longer separate. In many situations, they are the same.
- Technology is altering (rewiring) our brains. The tools we use define and shape our thinking.
- The organization and the individual are both learning organisms. Increased attention to knowledge management highlights the need for a theory that attempts to explain the link between individual and organizational learning.

- Many of the processes previously handled by learning theories (especially in cognitive information processing) can now be off-loaded to, or supported by, technology.
- Know-how and know-what is being supplemented with know-where (the understanding of where to find knowledge needed).

As theories of learning share many attributes and new ones build progressively on previous ones, any consideration of learning requires a review of existing theories. (Driscoll, 2000) categorizes learning into three broad epistemological frameworks:

1. Objectivism states that reality is external and objective, and that knowledge is gained through experiences.
2. Pragmatism states that reality is provisional, and knowledge is negotiated through experience and thinking.
3. Interpretivism states that reality is internal, and knowledge is constructed.

Analogic theories of learning consider that learning occurs inside a person. Even social constructivist approaches, which argue that learning is a social process, promote the role of the individual (and physical presence, i.e. brain-based) in learning. These theories do not address learning that occurs outside of people (i.e. learning that is stored and manipulated by technology). They also fail to describe how learning happens within organizations. When the existing learning theories are seen through the prism of technology, many important questions:

- How are learning theories impacted when knowledge is no longer acquired in the linear manner?
- What adjustments need to made with learning theories when technology performs many of the cognitive operations previously performed by learners (information storage and retrieval).
- How can we continue to stay current in a rapidly evolving information ecology?
- How do learning theories address moments where performance is needed in the absence of complete understanding?
- What is the impact of networks and complexity theories on learning?
- What is the impact of chaos as a complex pattern recognition process on learning?
- With increased recognition of interconnections in differing fields of knowledge, how are systems and ecology theories perceived in light of learning tasks?

3. Complex Networks and Connectivism

3.1 Complex Networks

The twenty-first century has begun intellectually under the paradigm of complex networks under the sign of the connection. In particular, the 1998 Nature paper (Watts, & Strogatz, 1998), entitled "*Collective dynamics of small-world networks*, is widely regarded as a seminal contribution to the new interdisciplinary field of "complex networks," whose applications reach from graph theory and statistical physics to sociology, business, epidemiology, and neuroscience. As one measure of this paper's impact, it is the most highly cited article about networks in the past decade, according to the ISI Web of Science. It was also the sixth most highly cited paper in physics, with 2700 citations, between January 1, 1998 and August 31, 2008.

The science of complex systems is a new multidisciplinary field aiming at understanding the complex real world around us. Complex networks allow the study of model complex phenomena in different contexts, and many scientific areas can be considered to fall into the realm of complex systems and can be studied by using nonlinear mathematical models, statistical methods and computer modelling approaches (Watts & Strogatz, 1998), (Watts, 1999), (Strogatz, 2001), (Watts, 2003), (Barabási, 2002), (Albert & Barabási, 2002), (Wang, 2002), (Newman, 2003), (Bornholdt & Schuster , 2003), (Boccalettia et al., 2006). The first models of networks were used by mathematicians to model real objects described by the theory of probabilities; these models are called random networks or random graphs. The random graph theory was founded by Paul Erdos and Alfred Renyi. A detailed review of the item is in the book (Bollobás, 1985). Moreover, physicists since the early twentieth century have used networks to describe various physical ordered structures. The paradigm of complex networks arose in the late twentieth century and early twenty-first century, when technology has allowed measurements in networks of various kinds and it has been empirically discovered that real-world networks are in an intermediate state between the networks ordered from the physical networks and random mathematical networks. Although many quantities and measures of complex networks have been proposed and investigated in the past few years, three quantities: the average path length, clustering coefficient, and degree distribution play a key role in the recent development of complex network theory and modelling.

Complex network has been a hotspot in study of abroad fields and achieves many meaningful results in mathematics, physics, biology, communication, economics and sociology. In fact any complex system in nature can be modelled as a network, where vertices are the elements of the system and edges represent the interactions between them. The study and characterization of the statistical properties of complex networks has received much attention in the last few years. It is shown by Barabási, Newman, Watts and many other researchers that a great variety of real networks exhibit a small world property and scale-free character.

The popularization of the World Wide Web (Bernes Lee et al., 1994), as a medium for commerce, communication, information sharing, and education has raised the profile of networks as a means of human organization. Research from fields as diverse as sociology, physics, information and knowledge (Benkler, 2006), and organizational effectiveness (Stephenson, 2002) suggest that networks fundamentally alter the hierarchical structure found in many traditional institutions. Academic journals reflect exponential growth in focus on complex networks in sociology (Borgatti & Foster, 2003), as well as mathematics, physics, chemistry, and other fields (Scharnhorst, 2003). The growth of interest in, and research on, networks as organizational models for all aspects of society is significant. The essential information that the complex networks provide us, is that the vast majority of natural and artificial systems, which could be modelled as networks, the measures undertaken to determine the nature of its topology, show us that these networks have a structure that is an interpolation between absolute order and complete randomness, the topology of these networks inhabits the "edge of chaos".

In a pedagogical perspective, the complex thinking is focused on learning to learn (E. Morin, 1999, 2001), (Clergue, 1997), (Mason, 2008). The digital age has led to significant changes in how knowledge circulates. Would have been a sort of off shoring on knowledge, to the extent that the same began to escape from the places, where the society had the legitimacy for learning. At present, there is a multiplicity of knowledge without a proper place or spaces not traditionally accepted for the production of knowledge. What differentiates the university from other institutions is the search for better ways of making explicit the extra-scientific conditions, and deconstructed by controlling their influence.

Networks, as models of organizing education, are part of a larger general shift, beginning in the second half of the 20th century, away from individualist, essentialist, and atomistic explanations to more relational, contextual, and systemic understandings (Borgatti & Foster, 2003), (Baumeister, 2005) status that networking is having an impact on all aspects of university life. Networks, while generally associated with the development of the Internet, have long served a vital role in the management of and functioning in complex information environments (Wright, 2007). Viewing networks as structural models for education and learning is the new context and this is the context and the new challenge, in which the university training is immersed.

A network can simply be defined as connections between entities a graph from a mathematical point of view. Computer networks, power grids, and social networks all function on the simple principle that people, groups, systems, nodes, entities can be connected to create an integrated whole. Alterations within the network have ripple effects on the whole. From a mathematical point of view a network can be defined as a graph with additional information on vertices and /or edges. A network $N = (V, E, T,W)$ consists of : a graph $G= (V, E)$, where V is the set of vertices or nodes and E is the set of pairs (i, j), with $i, j, \epsilon V$, called edges (or lines, links, ties, arcs) that denote nodes i and j are connected. Undirected lines are called edges, and directed lines are arcs. We will denote by n and m the cardinalities of the sets V and E, $n = cad (V)$, $m = card (E)$. T are vertex value functions: t: $V \rightarrow A$, and W are edge value functions: $w: E \rightarrow B$. Normally one imposes that $i \neq j$ so that self-connections are avoided. Along with this definition, we can also consider that the elements in E are ordered pairs $(i,j) \neq (j,i)$. In this case we will talk of a directed network (or diagraph). It is also very common to assign weights (numbers) to the edges so that we have a weighted (or valued) network. The cardinality of V and E can tell us about the nature of the graph.

Taking into account that the maximal cardinality of E is $\binom{n}{2}$ we will talk about a sparse network when $m << n^2$ and a dense one when $m \approx n^2$. The elements of the sets (V, E) receive different names depending on the context or scientific field in which we move. The following Table 1 shows some of them:

Scientifc Field	***V***	***E***
Mathematics	Vertex	Edge
Physics	Site	Bond
Computer Science	Node	Link
Sociology	Actor	Tie

Table 1. Networks are everywhere

3.2 Overview of Connectivism

The Connectivism is a theoretical framework for understanding learning developed mainly by Stephen Downes and George Siemens, (Downes, 2005, 2006, 2007), (Siemens, 2005, 2006, 2008). In connectivism, the starting point for learning occurs when knowledge is actuated through the process of a learner connecting to and feeding information into a learning community. Siemens (2005) states, "*Connectivism is the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning (defined as actionable knowledge) can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing*."

In the connectivist model, a learning community is described as a node, which is always part of a larger network. Nodes arise out of the connection points that are found on a network. A network is comprised of two or more nodes linked in order to share resources. Nodes may be of varying size and strength, depending on the concentration of information and the number of individuals who are navigating through a particular node (Downes, 2006). In this framework a community is the clustering of similar areas of interest that allows for interaction, sharing, dialoguing, and thinking together. According to connectivism, knowledge is distributed across an information network and can be stored in a variety of digital formats. Since information is constantly changing, its validity and accuracy may change over time, depending on the discovery of new contributions pertaining to a subject. By extension, one's understanding of a subject, one's ability to learn about the subject in question, will also change over time. Connectivism stresses that two important skills that contribute to learning are the ability to seek out current information, and the ability to filter secondary and extraneous information. The learning process is cyclical, in that learners will connect to a network to share and find new information, will modify their beliefs on the basis of new learning, and will then connect to a network to share these realizations and find new information once more. Learning is considered a knowledge creation process and not only knowledge consumption. One's personal learning network is formed on the basis of how one's connections to learning communities are organized by a learner.

The view of knowledge as composed of connections and networked entities, and the concept of emergent, connected, and adaptive knowledge provides the epistemological framework for connectivism (Siemens, 2005) as a learning theory. Connectivism posits that knowledge is distributed across networks and the act of learning is largely one of forming a diverse network of connections and recognizing attendant patterns (Siemens, 2006).

Principles of connectivism:

- Learning and knowledge rests in diversity of opinions.
- Learning is a process of connecting specialized nodes or information sources.
- Learning may reside in non-human appliances.
- Capacity to know more is more critical than what is currently known
- Nurturing and maintaining connections is needed to facilitate continual learning.
- Ability to see connections between fields, ideas, and concepts is a core skill.
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
- Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision.

The next table indicates how different theories of learning relate based on Ermer's and Newby's five questions (Mergel, 1998).

Property	***Behaviourism***	***Cognitivism***	***Constructivism***	***Connectivism***
How learning occurs	Black box—observable behaviour main focus	Structure, computational	Social, meaning created by each learner (personal)	Distributed within a network, social, technologically enhanced, recognizing and interpreting patterns
Influencing factors	Nature of reward, punishment, stimuli	Existing schema, previous experiences	Engagement, participation, social, cultural	Diversity of network, strength of ties
Role of memory	Memory is the hardwiring of Repeated experiences — where reward and punishment are most influential	Encoding, storage, retrieval	Prior knowledge remixed to current context	Adaptive patterns, representative of current state, existing in networks
How transfer occurs	Stimulus, response	Duplicating knowledge constructs of "knower"	Socialization	Connecting to (adding) nodes
Types of learning best explained	Task-based learning	Reasoning, clear objectives, problem solving	Social, vague ("ill defined")	Complex learning, rapid changing core, diverse knowledge sources

Table 2. Learning Theories (Siemens, 2008)

3.3 Network learning versus learning network

At this point, it is necessary to differentiate between Network Learning (NL) and Learning Network (LN). The first one is the logic-didactic-expert layer that determines the implementation of a learning network, while the second one is the set of software, hardware, institutions and even human factors that enable network learning. This is a subset of connectivism (Siemens, 2005). Downes provides connective knowledge as the epistemological foundation of connectivism (Downes, 2005).

"A property of one entity must lead to or become a property of another entity in order for them to be considered connected; the knowledge that results from such connections is connective knowledge".

The main goal of a LN is to change the traditional model of knowledge transmission (represented by a one-way teaching and learning) towards a new teacher-student relationship. In this case, the role of teacher has not the full knowledge, but this is distributed by peer groups. This forces to change the traditional role of the teacher in the classroom, and therefore gives a certain role outside them. A key idea is Learning Network strengthens the role of learning guides performed by teachers respect to the traditional class, which strengthens the role of teaching carried out by ones.

Why the Learning Networks are relevant in the implantation of the European Credit Transfer System (ECTS)? Currently, there is a fundamental change for the role of educational networks in Spanish University. What is the reason for so important change respect to the use of educational networks? The answer is ECTS, and therefore the educational university must be renewed. ECTS computes the student time inside classroom and laboratory, as well as study hours, time spent on exams and the one spent in the performance of guided works. This measure unit changes the university activity approach, so the teacher time giving a lecture must be decreased, while the student time "doing things" must be increased. The role of LN are going to perform in this new system is obvious. Teachers design the networks according to their knowledge areas, and turn into mentors for their use by students. The traditional class must be strictly designed to be employed for "everything" outside of LN. Students must to spend time of doing, to do in the LN.

4. Computer Algebra systems and Ada Augusta Learning Network

The symbolic calculus, formal calculus or computer algebra is used to perform mathematical calculations by using numbers, symbols, expressions and formulas in an accurate way, while the numerical calculus works only with floating point numbers (and therefore approximations).

The numerical and symbolic systems have evolved quickly, so quite powerful and versatile scientific computing systems have been released. These ones have many functions and tasks that facilitate solving mathematical problems. For this reason, systems of symbolic computation are very useful tools in science, technology, research, and particularly in the learning of scientific subjects. These systems have changed the use of computers in the learning of physical and mathematical areas.

You might think that the idea that computers running calculations with symbols, and as a result give us symbols, is a contemporary idea. The reality is that this idea was introduced in science, at the origin of computers, in the nineteenth century by Charles Babbage and Augusta Ada, (Larcombe, 1999), (Babbage, 1836), (Menabrea, 1961).

Lady Ada Augusta (1815-1852), Countess of Lovelace, which are daughter of Lord Bairon and, friend and patron of Charles Babbage (1791-1871) wrote [11]:

"There are many ways in which it may be desired in special cases to distribute and keep separate the numerical values of different parts of an algebraic formula; and the power of effecting such distributions any extent is essential to the algebraic character of the Analytical Engine. Many persons who are not conversant with mathematical studies imagine that because the business of the engine is to give its results in numerical notation, the nature of its process must consequently be arithmetical rather than algebraic and analytical. This is an error. The engine can arrange and combine its numerical quantities exactly as if they were letters or any other general symbols; and, in fact, it might bring out its results in algebraic notation were provisions made accordingly. It might develop three sets of results simultaneously, viz, symbolic results…; numerical results (its chief and primary object); and algebraic results in literal notation."

The Ada Augusta Learning Network (AALN) was formed taking the collaborative work made by members of some departments and knowledge areas from the University of Castilla la Mancha, Spain. Their beginning are two end of degree projects carried out in cited University (Miralles et al., 2004). The main goal of Ada Augusta project is to develop a learning network-assisted by using symbolic computation for the learning of scientific-technological subjects at university level.

The AALN is implemented by using WebCT as collaborative system and Mathematica (Wolfram, 1999) as symbolic calculus system by means of web technology. Particularly, *webMathematica* is a new technology allows the generation of dynamic web content with *Mathematica* (Wickham-Jones, 2001 & 2003). *webMathematica* adds interactive calculations and visualization to a web site by integrating *Mathematica* with the latest web server technology. This technology enables you to create websites that allow users to compute and visualize results directly from a web browser. You can find more details about this technology in Section 5.

The AALN has been consolidated through educational innovation projects funded by the University of Castilla-La Mancha, in the frame of support for educational networks (2006-2007 and 2007-2008). Fig. 1 shows the network in 2006. The colours represent the different campus teachers and the geometric shape to their knowledge area. The lines are the links teacher-to-teacher and teacher-to-core computing. The yellow node represents the computational core of the network. Note that student nodes do not appear in this network structure. This is a matter in progress from the connectivism point of view joint to the Social Network Analysis (SNA).

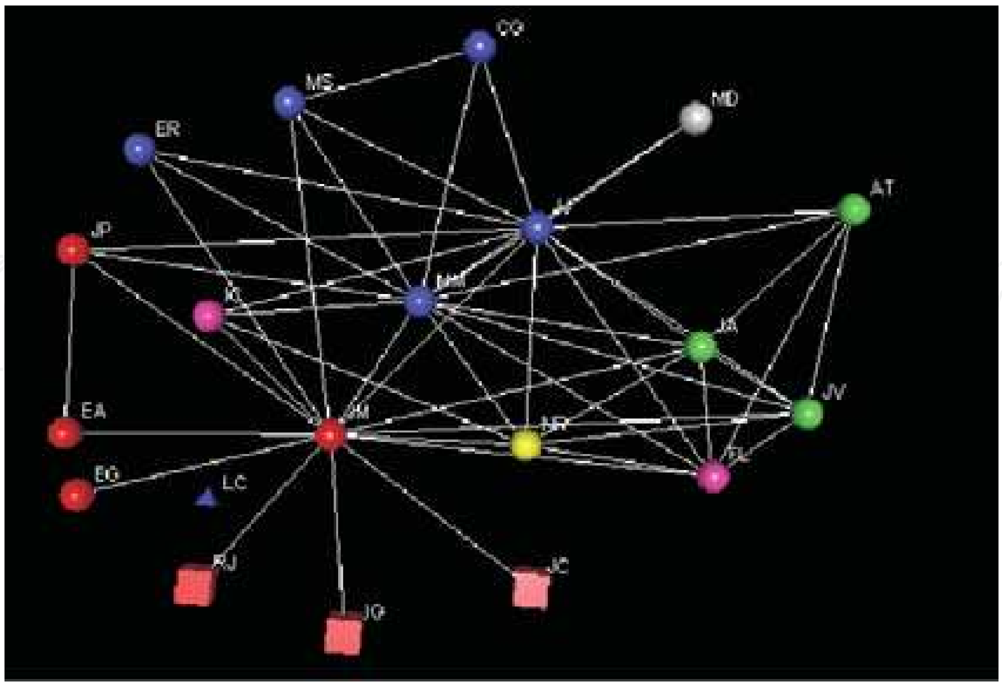

Fig. 1. Ada Augusta Learning Network

5. webMathematica: A Useful Web Technology for LNs based on Symbolic Computation

webMathematica is a new technology allows the generation of dynamic web content with *Mathematica* (Wickham-Jones, 2001). *webMathematica* adds interactive calculations and visualization to a web site by integrating *Mathematica* with the latest web server technology. This technology enables you to create websites that allow users to compute and visualize results directly from a web browser.

webMathematica and *Mathematica* have the same underlying engine, but they provide fundamentally different user interfaces and are aimed at different types of users. This web technology offers access to specific *Mathematica* applications through a web browser or other web clients. The standard interface provided requires little training to use effectively. In most cases, users neither have to be familiar with *Mathematica* nor need to know they are using *Mathematica*.

There are various important features that *Mathematica* can offer to a web site, including computation, an interactive programming language, connectivity, the *Mathematica* front end, and enhanced support for MathML. Also, there are several areas of use for *webMathematica*. Some of these include web computation, education, publishing, research, and hobbyist calculations.

5.1 webMathematica Technology

webMathematica is based on a standard Java technology called servlets (also in JavaServer Pages (JSP) technologies for v2.0). Servlets are special Java programs that run in a Java-enabled web server, which is typically called a servlet container (or sometimes a servlet engine). There are many different types of servlet containers available for several operating

systems and architectures. They can also be integrated into other web servers, such as the Apache web Server.
webMathematica allows a site to deliver HTML pages that are enhanced by the addition of *Mathematica* commands. When a request is made for one of these pages, which are called MSP scripts or MSPs, the *Mathematica* commands are evaluated and the computed result is placed in the page. This is done since v2.0 with the standard Java templating mechanism, JavaServer Pages, making use of custom tags.
webMathematica technology uses the request/response standard followed by web servers. A MSP script is processed as part of an HTTP transaction. A client sends a request to the server, which replies with a response. One feature of HTTP requests is that they can send parameters and values to the server. This is essential for any dynamic and interactive behaviour, because parameters are used to select and control the reply. The typical result of a request is an HTML page. However, it could be some other content type, such as a *Mathematica* notebook, or some form of XML.
A central component of *webMathematica* technology is the MSP servlet. This is used to process requests and return responses. The MSP servlet deals with each request in a separate thread, allowing more than one request to be processed at the same time. An overview of the workings of a *webMathematica* site is shown in Fig. 2. This is carried out since v2.0 by the kernel manager which calls *Mathematica* in a robust, efficient, and secure manner. The manager maintains a pool of one or more *Mathematica* kernels and, in this way, can process more than one request at a time (Wickham-Jones, 2003).

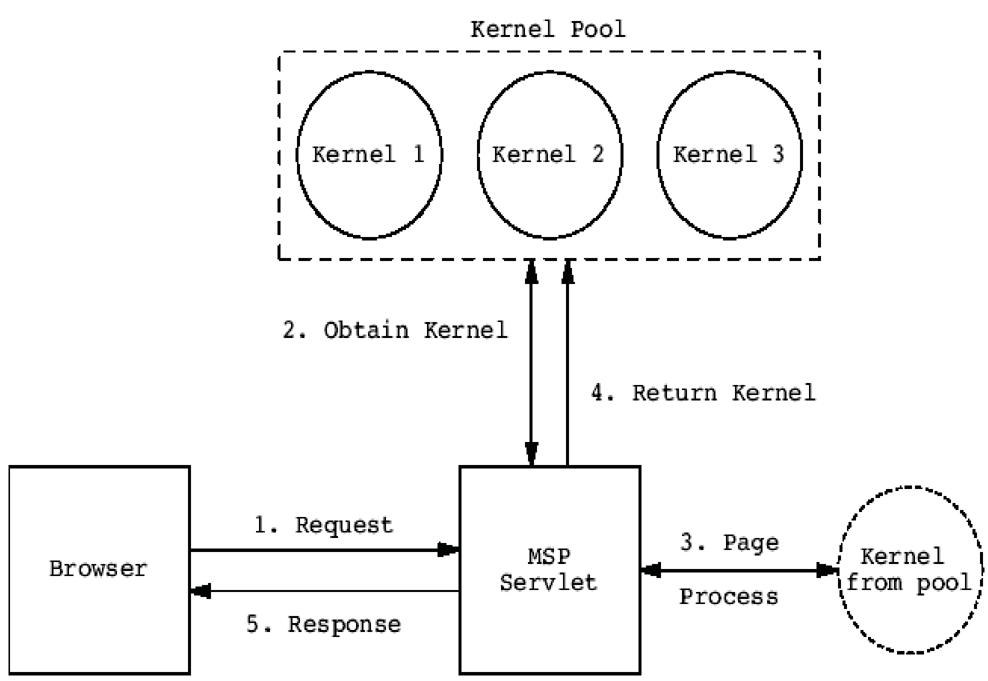

Fig. 2. Workings of a *webMathematica* site

- Browser sends request to *webMathematica* server.

- *webMathematica* server acquires *Mathematica* kernel from the pool.
- *Mathematica* kernel is initialized with input parameters, it carries out calculations, and returns result to server.
- *webMathematica* server returns *Mathematica* kernel to the pool.
- *webMathematica* server returns result to Browser.

5.2 Mathematica Server Pages

web*Mathematica* v1.0 provides a form of HTML templating based on what are known as MSP scripts. MSPs are standard HTML pages enhanced by the addition of Mathlet tags (`<%Mathlet expr %>`). When a request is made for
one of these pages, *Mathematica* replaces each Mathlet with the result of evaluating and formatting its contents. This usually builds a new HTML document, which is then returned to the client.

MSP scripting technology have been superseded in v2.0 by a new templating mechanism based on JavaServer Pages custom tags. This is a form of JavaServer Pages (JSPs) that use a special library of tags that work with *Mathematica*. JSPs support the embedding of Java into HTML, and are frequently used along with Java Servlets to develop large dynamic web sites. The library of tags is called the MSP Taglib and will work on any compliant servlet engine. One advantage of the use of a tag library is that it can completely hide any use of the Java programming language; this is the case with the MSP Taglib.

The two technologies are very closely related and it is straightforward to convert from one to the other. However, this Section only concerns MSP scripts. More information about *webMathematica* v2.0 can be found in (Wickham-Jones, 2003).

This example (see Fig. 3) evaluates the Date[] function of *Mathematica* each time a user requests the script. The result changes each time the script is requested, demonstrating that this is really a dynamic process.

```
<html>
    ...
    <body>
        ...
        <p>Its current value is:</p>
        <%Mathlet Date[] %>
    </body>
</html>
```

Fig. 3. Part of a sample MSP script

Of course, this example is not interesting, because the user is not doing anything other than retrieving a page. For interactive behaviour, a user needs to send input values with the request.

There are two kinds of variables in *webMathematica*: input variables and page variables. Input variables come with the HTTP request, for example from an input field in an HTML form. These can be identified in *Mathematica* code because they are labelled with a $$ prefix. Page variables are *Mathematica* variables used to hold intermediate values. They are called page variables since they are cleared when the page is finished. Additionally, support for HTTP session variables is provided since v2.0. These are stored in the server and can be

used in different pages. This can be useful for saving results from one computation to another. They last for the lifetime of an HTTP session.
The next example (see Fig. 4) demonstrates how variables are connected to input values. This is more elaborated because it contains form and input elements.

```
<html>
   ...
   <body>
      ...
      <form action= “Variables “ method= “post “> <!--Form head-->
          Enter something:
          <input type= “text “ name= “var “ align= “left “ size= “10 “>
          <br><%Mathlet $$var %><br>
          <input type= “submit “ name= “submitButton “ value= “Evaluate “>
      </form>   <!--Form end-->
   </body>
</html>
```

Fig. 4. Part of a sample MSP script

This example has two input tags: the first one allows the user to enter text, and the second one specifies a button that, once pressed, will submit the form. When the form is submitted, it will send information from input elements to the URL specified by the action attribute (in this case, the same MSP). Text entered into the input tag, which uses the name var, will be assigned to the input variable $$var.
The first time the page is accessed there is no value for $$var. When a value is entered in the text field and the Evaluate button pressed, $$var gets a value which is displayed. Note that the value is a *Mathematica* string —if you try and enter a computation such as "5+7", no computation is actually done. If you want the input to be interpreted and evaluated by *Mathematica*, you need to use one of the MSP functions (as MSPBlock or MSPToExpression) that are described in this Section.
webMathematica provides a large library of *Mathematica* commands to handle the many possible ways of working with *Mathematica* computations. Following, it gives a description of cited commands.

(a) MSP Functions: Variables
- MSPValue is a function that is useful for extracting the value of variables. Sometimes, it is useful to keep the user input each time the page is used.
- MSPValueQ is a useful function that tests whether variables have values.
- MSPSetDefault is a useful function for setting values of variables.
- MSPToExpression returns the interpreted value of a variable. Also, this function can take a format type for interpretation.
- MSPBlock is one of the key ways to work with variables from the HTTP request.

(b) MSP Functions: Showing and formatting results
- MSPExportImage is used to save an image using the *Mathematica* command Export.
- MSPShowAnimation is a convenient way to generate animated GIF images. The argument must be something that evaluates to a list of graphic objects.

- MSPLive3D is a convenient way to work with the LiveGraphics3D graphics applet. This applet displays *Mathematica* three-dimensional graphics and provides support for features such as interactive rotation and resizing.
- MSPFormat is one of the important ways to format results from *Mathematica*. The formatted result can appear in the different format types that *Mathematica* provides for output. In addition the result can be returned as HTML, an image content, or as MathML.
- MSPShow is the main way to include graphical results from *Mathematica* in an HTML page.

(c) MSP Functions: Returning general content

- MSPReturn allows a script to return something different from an HTML result.
- MSPURLStore stores a string of formatted data in the MSP servlet and returns a URL that can be used to retrieve the data.

(d) MSP Functions: Other relevant functions

- MSPInclude is a useful function that allows one MSP to include the result of processing another MSP.
- MSPPageOptions sets up global options concerning the current script.
- Several MSP functions throw an MSPException when some error situation appears. These are caught by the script processing code, but it would be permissible for a script author to catch them and process them in some intermediate step.

Also, new functions have been added in *webMathematica* v2.0.

5.3 Requeriments and Other Technical Issues

The aim of *webMathematica* technology is to reduce the amount of extra knowledge required for developing a site to a minimum. In practice, this means knowing something about HTML and *Mathematica*. *webMathematica* also aims to automate the management of the site to make running, maintenance, and configuration as convenient as possible.

The minimum technical components for *webMathematica*[1] are:

- A Servlet container supporting the 2.0 API (or higher)
- A Java Runtime Environment (JRE) 1.1 (or higher), Java 2 Version 1.3 (or higher) is recommended

There are many different combinations of hardware and operating systems that support these components. Most systems that run *Mathematica* will support *webMathematica*.

Two relevant files are web.xml and MSP.conf. The configuration file MSP.conf holds various site-specific parameters and may need modification for your site. The deployment descriptor file web.xml contains various settings that govern the operation of the web application.

The location for an MSP script is specified in the configuration file MSP.conf with the setting MSPDirectory. This directory is included on the *Mathematica* $Path, and is thus convenient for holding *Mathematica* packages or applications. Of course, you may not want to keep all MSPs in the same directory, preferring to place them in a variety of different locations. You

1 Requirements for v1.0

could then access each script with the url http://<your_server>/webMathematica/ MSP/<path_to_your_script>.

However, the way that web*Mathematica* v2.0 maps URLs onto JSPs is very straightforward. The URL names a JSP which lives directly in the web*Mathematica* web application or in a subdirectory.

For some applications, it is useful to use several pools of Mathematica kernels to serve different requests. You can configure the kernels in each pool differently, perhaps with different timeout parameters or different initialization files.

Running a general computation system like *Mathematica* inside of a web site is something that has many potential security hazards for the server. A major danger to any *Mathematica* site is that someone will try to send commands to *Mathematica* that may breach the security of the server. These commands can be sent as the value of input variables passed in from the server. However, *webMathematica* has a fully configurable security system, which is designed to prevent commands that may pose a security risk. You can set your own security model by placing a file in your MSPDirectory called SecurityConfiguration.m. However, the mechanism for locating the security configuration file has changed since v2.0.

The kernel monitor is a servlet that collects information on the running of your site. Upon access, the monitor brings up a page showing the current status of web*Mathematica*, describing various parameters of the site, and giving status information for each kernel.

You can find more information about *webMathematica* in (Wickham-Jones, 2001 & 2003).

6. Building a Learning Network based on Symbolic Computation

Following are described pedagogical elements for making real a Learning Network based on Symbolic Computation. Some resulting applications are also cited. They use previous web technology for generating practical and useful materials, which makes up a Virtual Laboratory. However, this Section is aimed on pedagogical purposes and not on technological ones.

6.1 Virtual Laboratory

The Virtual Laboratory is an interactive environment for creating and conducting simulated experiments: a playground for experimentation (Mercer et al., 1990). Several and diverses Virtual Labs can be found in research and educational areas.

Virtual Laboratory presented here consists of domain-dependent web applications which form a Learning Network[2]. Particularly, all applications are concerned symbolic computation.

Examples of applications for resolution of algebraic equations systems, Laplace transforms, resolution of electrical networks by means of loops method or Evan's Root Locus are given by AALN.

These applications require a diverse knowledge of *Mathematica* for users. There are applications absolutely transparent for them, who not need to know they are using *Mathematica*. Users are taken through a sequence of web pages in which they select different

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2 BSCW server of Department of Applied Physics (UCLM). http://www.maxwell.pol-ab.uclm.es
AALN webMathematica applications.
http://www.poincare.pol-ab.uclm.es/webMath

input parameters and submit data to build up a sequence of results. In opposite, *Mathematica* experience is required for other kind of applications. A user can type and submit a sequence of *Mathematica* expressions and receives a result.
Following are cited pedagogical elements for making these applications.

6.2 Interactive and Reusable Learning Units

We define Interactive and Reusable Learning Units (IRLU) as any small and programmable tools in which appear questions with a simple difficulty level. The answers of these questions are one or more algebraic expressions that must be written by the student. These answers are not made by means of a comparison between different expressions. This is one step more where the multiple choice tests or numerical results ones are not acceptable. The main advantage in the use of IRLU is the chance of admitting, answers which could be written in different ways but with the same meaning. It is needed that this programmable tool has a high performance for algebraic simplification. Due to this reason, they must be developed by modern Symbolic Calculus platforms. Also, these platforms should be low-cost in order to be widely used.
These tools must be reusable because they could be easily modifiable. In this way, we can get a lot of applications with only a few changes. They are apparently different but with the same structure. Below, we show some examples applied in different technological fields as Physics, Electricity and Systems Theory.
This is the basis scheme for our work:

1. Formulation of a question
   (a) In a concise way.
   (b) It will be allowed the insertion of figures.
   (c) Not promote the possibility of ambiguities in the nomenclature.
2. Specification (not available for the user) of the correct solution.
   (a) It must take the syntactic rules of mathematical package and be the most simple possible.
   (b) It must to distinguish between kind of two cases: one for the homogeneous solution (equal to zero) and others where they can appear anomalous but their solutions are correct.
3. To collect the answer of the user.
   (a) A previous planning is needed in order to make the response as short as possible and without ambiguous interpretations.
   (b) In all cases, they must include notes for leading users (some example of response possible and remainders of valid syntax)
4. Comparison between the correct solution and provided by user.
   (a) First task is calculating the ratio of available to correct solutions.
   (b) Next task is to make an algebraic simplification of this ratio using the symbolic program.
   (c) The solution given by the user will be right if the result of this simplification be the unit.
   (d) Sometimes it will be needed to take into account situations which look like to be maliciously made, but objectively they are good choices.
5. Notification to the user about the result obtained.
   (a) It can be a simple CORRECT/ERROR

   - (b) It is possible to make available the correct solution
   - (c) Another possibility is to make some learning suggestions depending on the result obtained.
6. Including information or help on demand (this is optional)
   - (a) It can include a guide (as a summary) of basic concepts with an flexible level.
   - (b) Anyway, the premise Reusable always is necessary.

The IRLU are very interesting because of they are easily programmable. It is possible to make a set of templates and then next IRLUs will be more simple to build. They can be associated in small conceptual modules and used in an aleatory way for the evaluation of the students. However, we can emphasize that they are very useful for the self-evaluation of the students, and this is a very important part in the new European Higher Education Area.
We show a basic example[3] of IRLU, for Electrical network theory. The formulation can be:
"Given the circuit in the figure, write resulting equation applying the Kirchhoff's Loop rule to the loop #1, in the form equation = 0"

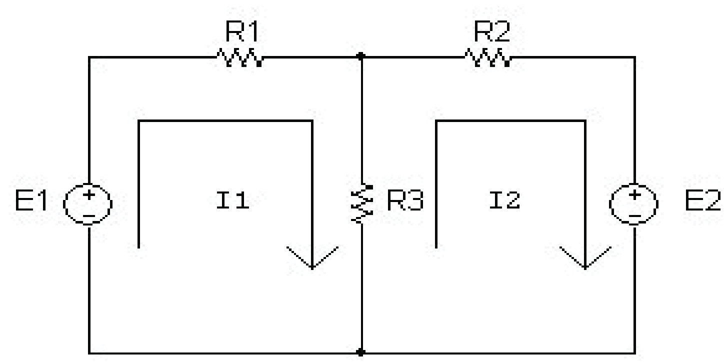

Fig. 5. Workings of a webMathematica site

Notes:

- It has to write in function of I1, I2, R1, R2, R3, E1 y E2.
- Different variables must be separated by some mark (white space is considered as multiplication)
- They can be careful with the Mathematica syntax (specially with capital and lower case letters)

A possible solution could be -E1+I1*R1+R3 (I1-I2) = 0
Anyway, other possible solutions are (for example):

- E1-I1*R1+R3(I2-I1) = 0
- -E1+(R1+R3)I1-R2*I2 = 0
- …

An appropriate design of these kind of questions is useful for reinforce the learning in an autonomous and solid way. In this sense, this is fundamental in the use of ECTS.

[3]http://www.maxwell.pol-ab.uclm.es:8080/webMathematica/MSP/users/jamartinez/circuitos/EjSym10-10

6.3 Applications based on Symbolic Computation for Supervised Works

In this section we describe the incorporation of Symbolic Calculus beyond the evaluation and support tasks to calculus (which are the 90% of cases). This is a different concept (more pretentious) that we can consider as part of guided learning. Our objective is not to replace the presentation lectures, but the student has a help in order to get the pre-established competences, for distance and net education.

Nowadays, there are a lot of application (SCILAB[4], Toolboxes de MATLAB[5], GNU Octave[6], Maple[7], Mathematica[8], …) in the field of technology that might be sufficient to achieve our goal. Nevertheless, this is not so. These packages are tools that use both teacher and student, but itself do not give the demanded guide by us. For example:

a) There are a subject (Systems Theory) that make use of a methodology (Evans, 1950) that allows to make a diagram which shows the roots variation when varies an adjustable parameter change (normally k) from 0 to $+\infty$. This procedure, known as Root Locus is very important in many applications of different fields. For this reason, the student must know how to construct this geometric site, trough the application of a series of simple rules. Some of the above mentioned computer applications have specific commands ("evans" in SCILAB, "rlocus" in Octave and MATLAB, …) that allow to construct graphically that figure. However the student must be able to construct this Locus Root by itself and then, to compare their result to provided by other tools. In this case, the applications require more exhaustive programming skills and will use the Symbolic Calculus tools for leading step-by-step to the student to get the correct result.

b) The simulation of electric and electronic networks from a numeric point of view is made since 70's. The program SPICE[9] is the most known. It is well established that the use of these simulators work in a different way like is used in teaching. The process of analysis of an electric network in the classroom has nothing to do with the management of these programs. However, if we applied appropriately Symbolic Calculus, we could get a similar analysis of an electric network both in the classroom and in the network. This would favour the auto-learning and then to get the desired objectives.

In both cases, we have to add two new components that not appear in the IRLU: to achieve the solution be found by the tool and, on the other side, the followed process for problem solving be available to the students, so they can make any look up in any time.

4 SCILAB is a trademark of INRIA. http://www.scilab.org/
5 MATLAB. http://www.mathworks.com/
6 GNU Octave. http://www.gnu.org/software/octave/index.html
7 Maple. http://www.maplesoft.com/
8 Mathematica. http://www.wolfram.com/
9 SPICE. http://bwrc.eecs.berkeley.edu/Classes/icbook/SPICE/

6.4 IRLUs' examples

In this subsection we will consider some examples of the use of IRLUs in different learning contexts.

Physics:

Let's use an example from dynamics of the particle. The ultimate goal is to verify whether the student has got the skill to obtain the resultant of forces acting on a body. The wording of the problem would be:

Expresses the component of resultant force (in the positive direction of x- axis) acting on the mass on the plane inclined at angle b, in the figure, as a function on the mass ***m****, the gravity* ***g****, the angle* ***b*** *and the coefficient of friction* ***u****.*

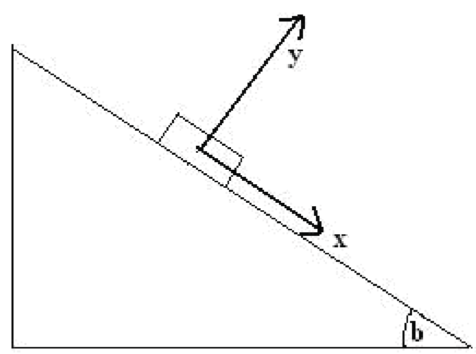

Fig. 6. Mechanical example

There are several different ways to write the correct answer. For example:
m*g(Sin[b]-u*Cos[b]) or Cos[b](m*g)(Tan[b]-u), or g*m*Sin[b]*(1-u*Cot[b]), or…

-Electrical network theory

Another example similar to that already indicated in this field, but where it is permissible to ask several things at once:

For the network in the figure, writes the right expressions (according to Ohm's Law) V1=__________________________ and V2=______________________ Write the equation of loop (without using Ohm's law)__________________________=0.

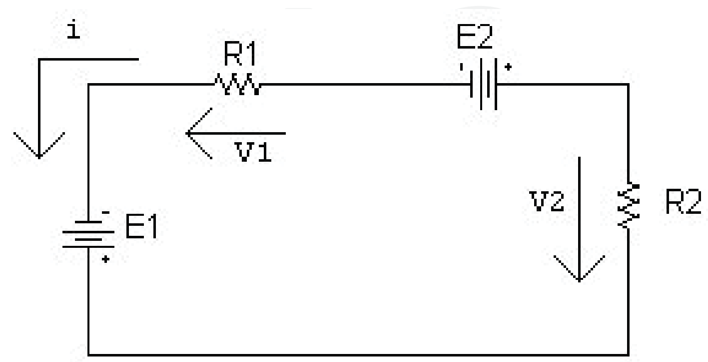

Fig. 7. Electrical network example

Control Systems

The most common technique used for model linear, time-invariant systems in control systems, is the block diagram, with the mathematical model represented as a transfer function. One of the first steps is to obtain the overall transfer function equivalent of the entire system. If the system is complex, the level of simplification is often different depending on the procedure (although the result should be unique). The way to verify the accuracy of the final result is to simplify previously compared with the correct solution. Two examples of use could be:

a) In the following block diagram, you must to express the transfer function equivalent of the overall system, using algebraic techniques from block diagrams.

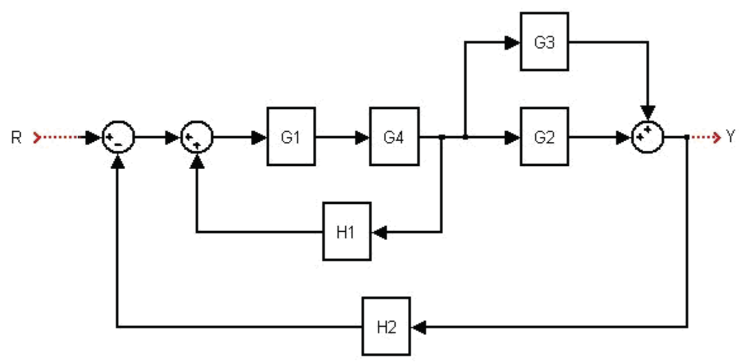

Fig. 8. Control systems example 1

b) Write the final transfer function for the following system, using Mason's Rule.

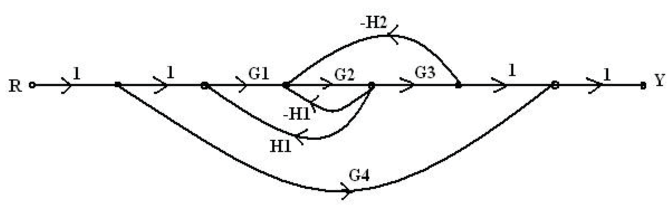

Fig. 9. Control systems example 2

As you can see, the scope is very extensive. In order to implement the computer program, the general procedure is to make a template-type, and change both the wording and the display-figure and of course, indicate the correct solution in each case. We can create different templates (e.g., based on the number of responses we want to ask) and then reused it in the subjects where we consider appropriate.

The examples discussed in this paragraph and others are available at the following URL: http://www.poincare.pol-ab.uclm.es/webMath

7. Conclusions

This chapter presents a model for the teaching assisted by network in the framework of connectivism as a learning theory in the digital age. Following are showed the main conclusions:

- The effort of building a computational kernel for a learning network based on symbolic calculus has been established inside of connectivism context.
- Connectivism has been considered as the best model to guide the process of creating a network learning.
- It has developed a computational core for a learning network through symbolic calculation and using webMathematica technology.
- The kernel of symbolic calculus in the learning network is considered as capable of fostering the interaction among teachers from different Scientific-technical subjects in the ECTS context.
- It has developed a set of interdisciplinary, interactive and reusable learning units, based on symbolic calculus and supported by the computational kernel of the learning network.
- A work in progress is to decide how to introduce the nodes: students, teachers and subjects, in the developed learning network, according to the connectivism paradigm.
- Another work in progress is to introduce the measures from complex networks topology, in order to evaluate the performance of network learning.

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The widespread deployment and use of Information Technologies (IT) has paved the way for change in many fields of our societies. The Internet, mobile computing, social networks and many other advances in human communications have become essential to promote and boost education, technology and industry. On the education side, the new challenges related with the integration of IT technologies into all aspects of learning require revising the traditional educational paradigms that have prevailed for the last centuries. Additionally, the globalization of education and student mobility requirements are favoring a fluid interchange of tools, methodologies and evaluation strategies, which promote innovation at an accelerated pace. Curricular revisions are also taking place to achieved a more specialized education that is able to responds to the society's requirements in terms of professional training. In this process, guaranteeing quality has also become a critical issue. On the industrial and technological side, the focus on ecological developments is essential to achieve a sustainable degree of prosperity, and all efforts to promote greener societies are welcome. In this book we gather knowledge and experiences of different authors on all these topics, hoping to offer the reader a wider view of the revolution taking place within and without our educational centers. In summary, we believe that this book makes an important contribution to the fields of education and technology in these times of great change, offering a mean for experts in the different areas to share valuable experiences and points of view that we hope are enriching to the reader. Enjoy the book!