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Electronic education system model

Elsabé Cloete *

Department of Computer Science and Information Systems, UNISA, PO Box 392, 0003 South Africa

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Abstract

E-learning¹ efforts and experiments currently receive much attention across the globe. The availability of electronic and web-enabling technologies also dramatically influences the way we view the learning strategies of the future [Kramer, B. J. (2000). Forming a federal virtual university through course broker middleware. In *Proceedings: LearnTec 2000*. Heidelberg, Germany, 2000. Hiltz, S. R. (1995). Teaching in a virtual classroom. In *Proceedings: International conference on computer assisted instruction.(ICCAI'95)*, Taiwan, March 1995]. However, due to disappointing experiences in wide spread implementation of computers in schools [Foshay, W. R. (1998). Education technology in schools and in business: a personal experience. *Education Horizons*, 66(4),154–157], many are already predicting the failure of web technologies for learning [Rogers, A. (2000). The failure and the promise of technology in education. Global SchoolNet Foundation, 27 May 2000 (<http://www.gsm.org/teacharticles/promise.html>)]. It is indeed likely that e-learning, making use of technological advances such as the Internet, may also be dissatisfying and frustrating unless we design electronic educational models that can avoid potential complications. In this paper, we define and describe an electronic educational system model (EES model). The aim of this model is to assist the designers of different e-learning settings to plan and implement a specific learning situation, with the focus on the individual requirements and milieu of the learning group. The EES model is composed of four layers, each consisting of different objects (components) addressing issues specific to each layer. When constructing a learning situation, the planners, schedulers and facilitators come together with a clear view of their particular learning situation in mind. They then use the EES model to design their course layer by layer, including objects from each layer. Each object consists of one or more methods/strategies to be implemented in order to achieve the learning objectives of the course. This approach promises to increase the chances of successful and quality implementations [Cloete, E. (2000). Quality issues in system engineering affecting virtual distance learning systems. To appear in *Proceedings. COMPSAC'2000*. Taiwan, October 2000] with as few frustrations and disappointments as possible. © 2001 Elsevier Science Ltd. All rights reserved.

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* Tel.: +27-12-4296712; fax: +27-12-4296771.

E-mail address: cloete@unisa.ac.za

¹ Electronic learning (e-learning).

1. Introduction

The Internet and network-centric computing have laid a firm foundation for experimentation with e-learning and stretched traditional learning paradigms through electronic and web technologies into new dynamic learning models (Eckert, Geyer & Effelsberg, 1997). Several factors highlight the advancing importance of incorporating electronic learning into curriculums and compel educational institutions to cater for the needs of continual training and retraining of their clients (Bosua & Cloete, 1999). Examples of the factors that can make people clamour for electronic access to educational services include the impetus of market forces, the availability of technology and customer pressure. Institutions that take these factors and demands seriously have already introduced structures to make e-learning possible for those students who are not (cannot be) present on campus. However, new challenges face the institutions that adopt e-learning paradigms and support infrastructures that were necessary for the success of traditional learning paradigms may not be relevant in e-learning paradigms. For example, large printing and despatch departments that previously provided course material in paper format, might experience being redundant in the e-learning paradigm.

Because enabling technologies present many opportunities as well as challenges in the realizing of e-learning, it is imperative that educators and institutions planning to embark on the development of e-learning systems, have a clear and accurate understanding of the capabilities, limitations and influences of these technologies (Cloete, 2000). Creative approaches and competent strategies to manage these limitations at the instructional design, the user levels as well as integration to other systems, need to be established and understood in order to ensure a degree of quality comparable to that of traditional learning. Without the integration of well-established methods and techniques, many of the e-learning efforts may be futile, leaving frustrated facilitators and badly educated students in their wake (Cloete, 1999).

The objective of this paper is to provide an electronic education system (EES) model through which designers can construct a specific learning situation when embarking on the design of an e-learning system (see Fig. 1). Effective strategies can be designed before entering a specific learning situation, and thus improve the chances of facilitating successful e-learning of a high quality. The

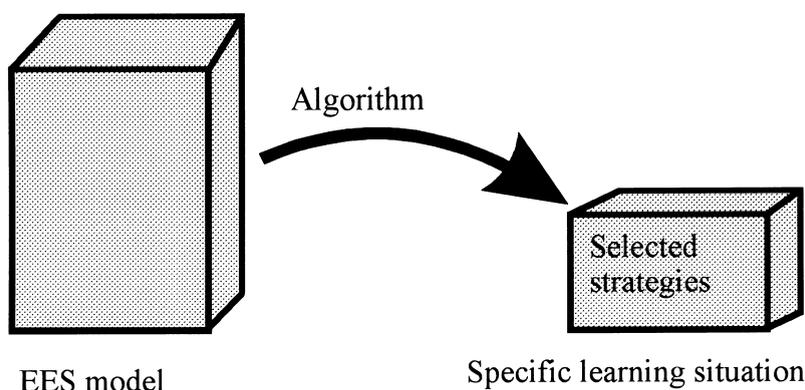


Fig. 1. Mapping the EES model onto a specific e-learning environment.

mapping from the EES model onto any specific learning situation is possible through a number of algorithms.

In the next few pages, we propose the EES model that allows planners, schedulers and facilitators to build a specific learning situation. Since e-learning environments are often different from one another, the designers select specific objects and methods from the EES model that are appropriate to the particular implementation environment. The specific learning situation also generates a workflow engine for its implementors. Section 2 introduces the EES model and summarises the ontology of terms used in this model. Section 3 describes two algorithms to design a specific learning situation. Section 4 illustrates the mapping of the EES model onto a specific learning situation whilst Section 5 summarises the paper and describes the areas that we are currently exploring in follow-up research.

2. The EES model ontology

2.1. The EES model

A four-tier EES, model as described in Fig. 2, permits a full range of services in the construction of a specific learning situation. Procedures are defined within each of these tiers, facilitating the design of, and suggesting a subsequent workflow structure for, a specific learning situation. Such a learning situation consists of selected objects and specific methods (within the selected object) that are appropriate within the boundaries of the implementation environment. The four-tier EES model, in particular, permits the interaction between selected methods to be defined so that learning may be achieved effectively within the boundaries of the available technologies.

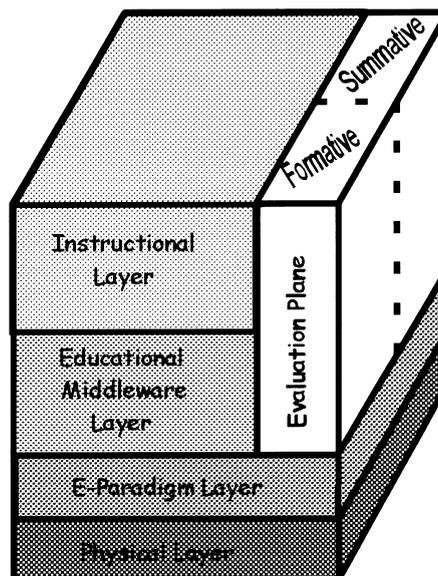


Fig. 2. Four-tier model for electronic education system.

2.1.1. A layered model

The basic structuring technique in the EES model is layering. In terms of this approach, every electronic educational system or situation is composed of an ordered set of layers. Each layer represents a subsystem that is constructed from a selection of related service objects.

An object within a layer is defined by a specific set of functions, relating to that layer, that it is able to perform. Each of the service objects consists of a collection of methods. A method describes the specific strategy that is used to accomplish the service being offered by the object. Using an analogy, the EES model can be compared to a filing room containing four filing cabinets (the four layers), with each cabinet having several filing folders (objects). Each folder includes one or more documents (methods).

In e-learning, many methods exist that can realise specific outcomes, but the method or strategy followed to acquire these outcomes often relies on circumstances of the specific e-learning environment. For example, consider course communication within a course. We call *course communication* an object. Methods for this object include *e-mail, telephone, fax, postal mail, discussion forums, chat rooms, news groups, video conferencing*, etc.

2.1.2. Service objects and methods

Each general object within a layer may be made specific by the selection of one or more methods that determine the attributes of that object. To supply a practicable learning situation, some objects are considered mandatory for inclusion during the design, while others are optional. Returning to our example of the *course communication* object, we find that the issue is not whether to include or exclude this object (thus a mandatory object), but we merely need to know which methods of this object to incorporate. Furthermore, the design will also often include one or more methods from the same object. For example, in the course communication object, it makes sense to include more than one form of communication in a strategic plan.

2.2. Workflow within the EES model

The layered approach enables us to define a workflow between the distinct layers. Each (N)layer, except the bottom layer, is supplied with a set of services, these being compiled from selected objects on the ($N-1$) layer. (The bottom layer is assumed to be compiled from a set of telecommunication technology objects, this being the standard electronic infrastructure that is required for the specific learning situation.) The layer-to-layer workflow is described as follows: an (N)-layer provides its ($N+1$)-layer with a set of services, and uses the services of its ($N-1$)-layer. The top layer provides the EES model with transparency in that the students and facilitators are furnished with a set of services in a setting where learning is promoted. The workflow between the layers is shown in Fig. 3.

2.3. Layer descriptions

2.3.1. Instructional layer (top layer)

The purpose of the *instructional layer* is to serve as a window between the learning process and the underlying strategies necessary to establish the learning environment. As with the

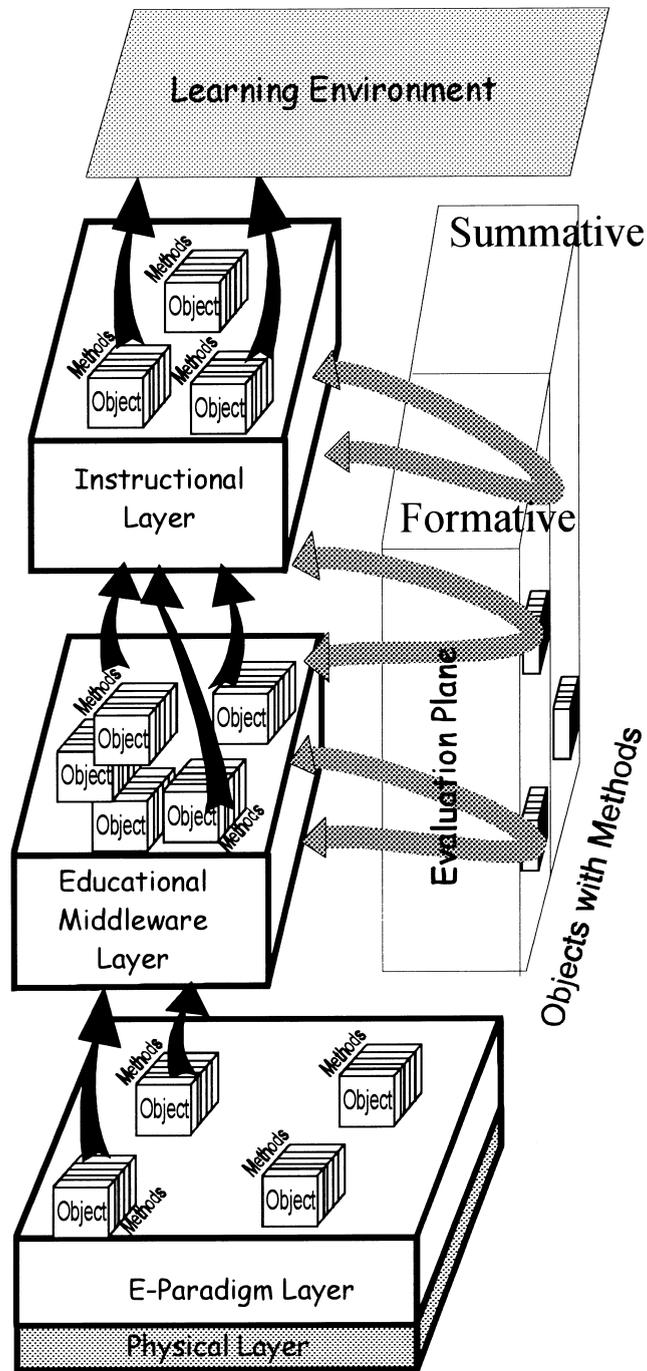


Fig. 3. Workflow between the layers of the EES model.

other layers, the *instructional layer* is composed of various objects, each containing one or more methods. For the sake of clarity, we describe two objects on this layer.

Let us return once again to our *course communications* object. The *course communication* object on the *instructional layer* provides the means necessary for communication between students and their facilitator and also for communication and cooperation between students. As mentioned above, there are many methods for this object. When designing a specific learning situation, the designers may decide to include only *e-mail* for *course communication* or provide their structures with a richer communication environment by including *telephone*, *discussion groups*, and *chat facilities* as the means of *course communication*.

In a second example, we describe the *pedagogic paradigm* object from the *instructional layer*. The *pedagogic paradigm* object provides the means by which the students are exposed to course content and gain skills such as critical thinking, deeper understanding, problem solving, writing, construction, etc. Some of the methods that may be included in this object are (1) learn-by-reading (2) learn-by-discovery (3) learn-by-doing (4) cooperative learning, etc. When designing a specific learning situation, it is clear that one or more of these methods may be included to provide a more sophisticated learning environment. (Some of these methods are objects in their own right since there may exist several strategies that should be investigated and decided on before just including the specific method.)

From the two object examples described above, it can be seen that there is also a relation between the different objects. The selection of methods from one object enforces the inclusion (or exclusion) of methods from other objects. For example, the inclusion of the *cooperative learning* as a *pedagogy method* calls for the inclusion of *course communication methods* which make *cooperative learning* possible.

2.3.2. Educational middleware layer

The *educational middleware* layer provides services for a reliable and effective learning environment. It accomplishes this task by supplying a set of tools to support educational programmes such as managing access for retrieval of courseware, authorising data entries to the server, providing a central repository structure for course material, with efficient storage mechanisms optimised for different media types with indexing and retrieval facilities. Three other major functions on this level include the provision of an integrated user interface, with the objective to buffer the student from the technology behind the content, the establishment of enabling technologies for electronic submissions of assignments for automatic assessment and grading, and the integration of the learning environment with other institutional systems.

Once again we highlight our discussion with an example of an object with its methods that is available on the *educational middleware* layer. The object, *assignments*, forms part of the *instructional layer's* object collection, but *assignment submission* is an object dealing with the reliable acceptance and delivery of assignments, and thus belongs to the *educational middleware* layer. Some of the methods that may be included in this object are (1) paper-based assignments through postal mail (2) electronic attachments to e-mail (3) web-based submission form (4) specific specialised software, etc. For this specific object, the method depends strongly on the class structure, the type of assignments, as well as the support infrastructure available to the facilitator. For example, if an assignment consists of an essay, the class structure is fairly small (25 or less), and the facilitator is a pioneer in electronic learning (thus has little support infrastructures available),

submission of the assignment as an e-mail attachment may be acceptable. However, if the class size increases, the overhead associated with e-mail attachments, such as saving individual files in a course directory, often having to rename them first, or saving each file in its own directory combined with the maintenance of such a structure, etc., becomes a daunting task for individuals without a proper support base.

2.3.3. *Electronic paradigm layer*

The objective of the *e-paradigm* layer is to provide an electronic learning paradigm composed of technological strategies possible in electronic learning. The objects found on this layer form the basis of the specific learning situation. They often prescribe which objects from upper layers may be suitable for selection. We highlight our description once again by using an example of objects from this layer.

The *synchronous* and *asynchronous* objects are commonly identified on the *e-paradigm* layer. In *synchronous*² learning environments geographically dispersed, students and lecturers share a virtual classroom within the same physical time frame. Examples include remote lecture rooms with video conferencing, or students attending real-time lectures from home. The *asynchronous* object is characterised by its being independent of location, time, and learning speed of the learner. A typical example is that of the learner who prefers to study at his/her own pace and time. The number of methods for objects on this layer is limited, and is realised on other levels. For example, selection of the *asynchronous object* will have a direct influence on the methods of the *course distribution* object found on the *educational middleware* layer. Methods may be through *web downloads* or precompiled *CDs* while in the *synchronous* environment, *e-books* and *on-line material* may be more relevant.

2.3.4. *Physical layer (bottom layer)*

The *physical layer* provides for the transparent transmission of messages (which may be course communication, course material or course directives) between students and lecturers tied together in an e-learning scenario. The *physical layer* includes the specification of hardware and software technology objects necessary to accomplish e-learning. The number of methods included in these objects is usually limited to one but may sometimes extend to two. For example, an object on this layer may be an *Internet connection*. The methods of the *Internet connection* object describe the *prerequisite hardware* and software strategies necessary to accomplish an *Internet connection*.

2.3.5. *Evaluation plane*

An evaluation plane stretches across the top two layers. This plane performs evaluation functions related to these two layers as a whole. The purpose of the *evaluation layer* is to determine whether or not the methods selected from the *instructional layer* and from the *educational middleware* layer are accomplishing the established goals and objectives.

The analysis performed by this plane and subsequent conclusions that are drawn, provide coordination between the top two layers. Similar to all layers in the 4-tier model, the *evaluation plane* is composed of objects with sets of methods. The *evaluation plane* is divided into two sub-planes.

² *Synchronous* refers to “online” while *asynchronous* refers to “off-line”.

A sub-plane (or sub-layer) is described as a grouping of service objects in that plane (or layer) which may be bypassed. The evaluation plane is divided into a *summative evaluation sub-plane* and a *formative evaluation sub-plane*. Formative evaluation is typically conducted during the lifetime of a process, whereas summative evaluation is conducted at the end, or after the lifetime of a process (Wills, 1995). In an e-learning system, one may for example choose to do both types of evaluation and must then include objects from both sub-planes, or one can include only one type of evaluation, analysing one's learning situation through various methods (from selected objects) as found in that particular sub-plane.

For example, an object on the *summative evaluation* sub-layer may be the *quantitative evaluation* object. Quantitative evaluation relies on a breadth of response and is patterned after experimental research focussed on the collection and manipulation of statistically relevant quantities of data (Wills, 1995). The methods of the *quantitative evaluation* object will typically describe strategies to gather data as well as strategies for the statistical manipulation of relevant quantities of the acquired data.

3. Algorithms to design a specific learning situation

There are many approaches to the design of an e-learning situation by mapping the EES model onto a specific environment. We consequently describe two algorithms before we conclude with an implementation example. A *top-down* algorithm and a *bottom-up* algorithm are two natural approaches to the design of a strategic model for a particular e-learning situation. The *top-down* approach is preferable where the options available on the *physical layer* are not restricted. For example, where all students have full-time access to the Internet, there is no restriction and any *e-paradigm* object may be selected, because the underlying services are available. The *bottom-up* approach is suitable where limitations exist on the *physical layer*, such as restricted Internet access. In the next two sections we describe the progression in each of these two approaches.

3.1. Top-down approach

In the *top-down* approach, planners, schedulers and facilitators initiate the mapping of the EES model onto the specific learning situation by first selecting objects from the *instructional layer* to be incorporated into their design plan. The services necessary to realise the chosen objects are then selected from the *educational middleware layer*. Other objects on the *educational middleware layer* which may not be of direct service to the objects from the top layer, can also be identified. The objective of these additional objects will be to enhance and enrich the infrastructure of the learning environment. However, the methods of objects on the *educational middleware* layer are often labour-intensive and require a well-established base of support. If embarking on an innovative e-learning effort without the backing of a support group, one should be very careful not to select sophisticated methods within objects from this layer.

The target group of students and the objects chosen from the top layers will often suggest the objects and the methods to be selected on the *e-paradigm* and the *physical* layers. For example, selection of a *video-conferencing* method (from the *course communication* object on the *instructional layer*), and a *specialised virtual classroom software* method (from the *interface* object on the

educational middleware layer), suggest the selection of a *synchronous paradigm* object from the *e-paradigm layer*, with a *permanent connection* object from the *physical layer*.

3.2. Bottom-up approach

In the bottom-up approach, the course designers are often limited in their course design by restrictions on the *physical layer* such as restricted Internet access. It, therefore, makes sense to take these restrictions into account and select objects and methods from the bottom layer, before considering the specific *e-paradigm* of the target group. Once suitable objects and methods from the *e-paradigm layer* are selected, one can eliminate certain (obvious) objects from the *educational middleware layer* that might only be suitable for courses in unrestricted environments, or move straight on to the next step where designers consider the desired instructional environment for the planned course. Objects and methods matching the desired goals and pedagogy of the course can subsequently be selected from the *instructional layer*. The services necessary to realise the chosen objects from the *instruction layer* are then selected from the *educational middleware layer*.

In both approaches, the final steps include the selection of such *evaluation objects* and *methods* as the designers and facilitators wish to implement. Although evaluation is often neglected, we wish to stress the importance of including objects from the *evaluation plane*. Identification of strengths and successes, and also of gaps and weaknesses in the instructional process is equally important to ensure effective and quality learning. Only by analysing the results of evaluation data that were gathered by a method included in the design of the course, can these goals be achieved. Fig. 4 illustrates the progression in workflow when designing an EES strategic e-learning model using the top-down approach or the bottom-up approach.

4. Implementation example

In this paragraph we describe a very simple e-learning situation in order to illustrate the mapping from the EES model onto our learning environment. Take note that there are many variations and other solutions to the example that we outline below, but our objective is to describe one possible simple solution for this learning environment. We make the following assumptions regarding our example learning environment: In a traditional distance education environment, we plan to run a short course, namely, *Introduction to computer networks*, through the WEB. Our infrastructure is such that we have access to a web and news server, but have to set up and maintain it for ourselves. Target students are full-time employed and want to study at their own time and pace. When analysing the given information, we observe that there are distinct group constraints because the target students prefer to study at their own time and pace, and thus our course design is dictated by the bottom-up algorithm.

As a first step, hardware technology and software technology objects are selected from the physical layer. A “PC with a minimum of 128 K RAM and 1 GB free hard drive space”, with a “modem capable of 28.8 kbps to an ISP (or other Internet connection)”, and “a permanent e-mail address” as suitable methods for hardware technology. Methods for the software technology object include “the Windows 95 (or higher) operating system”, “an Internet Browser”, and “e-

mail software (often included in browser)”. On the e-paradigm layer we select the *asynchronous* object.

Since it is not the objective of this paper to describe all possible objects on each layer, we do not eliminate any specific objects on the *educational middleware layer*, but proceed to the next step. On the *instructional layer*, we design our course around the outcomes that we wish to accomplish. Since *outcomes* differ from course to course, outcomes can never be specified as a generic object with methods. With the outcomes in mind, we rather focus our attention on the *pedagogy object* and then select suitable methods to realise our outcomes. The methods of this object often direct facilitators to include certain other objects. For example, if we choose the “*cooperative learning*” method, we must make provision for group work through our *course communication* object. Other objects that can assist us in realising our objectives, include *study material*, *assignments*, and *examination*. It becomes clear from this example, that each selected object forces us to think thoroughly about *what* we plan to do, as well as *how* we plan to accomplish our goals.

The “how”-part of our planning is addressed by the *educational middleware* layer. For the purpose of this example, let us consider only two objects on this layer. In the previous step we chose “*cooperative learning*” as a *pedagogy* method. For *cooperative learning*, we plan to have

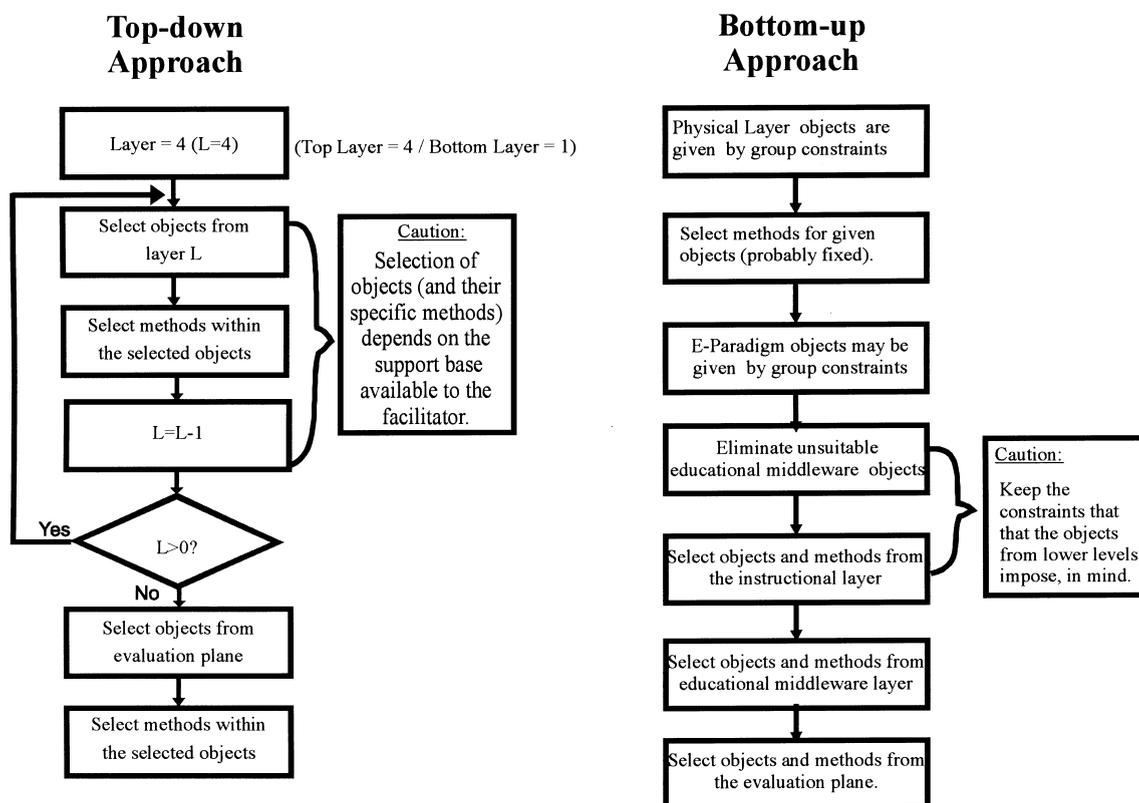


Fig. 4. Top-down approach (left) and bottom-up approach (right) to design a strategic e-learning model.

small work groups of two students per group. For this type of grouping *e-mail* is a suitable method, which already forms part of our selected *course communication* object on the *instructional layer*. On the *educational middleware* layer this implies the need for a mail server and the setup of a course e-mail address.

Another object on this layer is that of the *course interface*. Many commercial e-learning interface applications are available, but often require a reasonable support infrastructure for implementation and maintenance. Facilitators have the option to buy into a specific technology, design and program an interface which is tailored to their needs, or set up a few simple HTML pages. In a learning environment where the institution has its full weight behind e-learning efforts, buying into commercial applications, or designing a tailor-made interface might be the best solution, but in the initial stages of e-learning, simple HTML pages might be less of an overhead burden on the facilitator. We thus chose simple HTML pages for our course.

To make sure that our efforts are reasonably successful and learning as we planned it, takes place, we include both *formative* and *summative evaluation* objects. Although the ideal would be to include other departments, such as Psychology and Statistics, in this process, your innovative effort does not yet lend itself to such depths. For the *formative evaluation* process we design a number of short questionnaires to prompt the students at the end of certain events. Each questionnaire focusses on a specific topic and requires a simple reply and a possible elaboration. For example, three weeks after the course has started, the students are prompted with a questionnaire form based on and course access. The questions “Did you manage to access the course easily?” and “If not, why not?” would be sufficient. It is our experience, at the most students simply do not have the time to work through lengthy questionnaires, and as a result do not respond to these.

To set up an effective *summative evaluation* questionnaire requires some professional input. However, in innovative efforts, a simple evaluation is better than none. One way of setting up a summative evaluation form is to use the objects from the instructional level, as well as some of the *educational middleware* layer and ask simple questions (similar to those in the formative evaluation forms) on each topic. Keeping questions simple also enhances the possibility of interpreting results correctly and incorporating comments into the planning of the next course.

5. Conclusion and future work

The importance of advanced electronic technologies, such as the Internet, to education has increased significantly during the past few years. In order for electronic learning systems making use of these technologies to be successful, effective and of a quality comparable to some of the traditional educational learning systems, the electronic learning systems must be designed and constructed with care, using a scientific approach embracing well-designed procedures and techniques.

In this paper, we defined a four-tier electronic educational system (EES) model. The objective of this model is to supply a basis for designers, developers and facilitators to construct practicable strategic e-learning models suitable for their individual e-learning environments. By using a layered approach, we separated different related functions into logical units which make it easier to design and maintain a flexible strategic e-learning environment.

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