QEF- Quantitative Evaluation Framework
Evaluating Educational Software

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ABSTRACT
In this paper we propose a Framework QEF (Quantitative Evaluation Framework) to evaluate educational software systems built with X-TEC (Techno-Didactical Extension for Instruction/Learning Based on Computer) model, in order to validate and strengthen the potential quality of e-Learning systems. The Quantitative Evaluation Framework evaluates the Educational software quality on a three dimensional space. Each dimension aggregates a set of factors. A given factor is a component that represents the system performance from a particular point of view. The quality of a given system is defined in a tri-dimensional Cartesian quality space and measured, in percentage, relatively to a hypothetically ideal system, represented in our quality space.

KEY WORDS
Computer based learning, educational software development, instructional design, learning environment, educational software evaluation, software engineering.

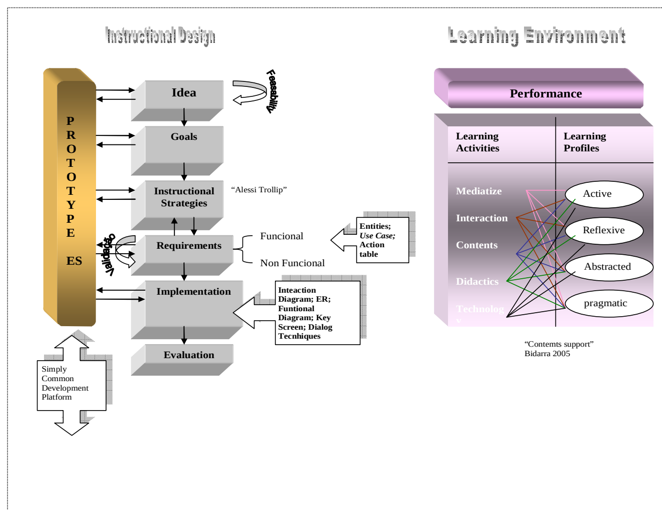
1. Introduction

Despite the theoretical benefits that e-learning systems can offer, difficulties can often occur when systems are designed without consideration of learner's characteristics (Fredman and Liu, 1996; Liang and McQueen, 1999).
In general, educational software systems are based on methodological approaches which are fundamentally concerned with processes or data.
The gap between the typical skills and terminologies of these two stages usually leads to a problem: the final product is far away from the initial requirements proposed by the author. Consequently, these approaches usually imply the high risk of obtaining low quality products. The X-TEC model tries to solve this problem (Escudeiro Paula and Bidarra José, 2006)
To evaluate the educational software systems based on X_TEC model we propose a generic Quantitative Evaluation Framework (QEF). This framework may also be applied to evaluate other Educational Software Development Models (ESDM), allowing for a direct comparison between different tools.
The process of creating these models is supported by the software engineering paradigm proposed by Pressman.

2. X-TEC Conceptual Model

The X-TEC model presents two overlapping extensions: instructional model and learning environment. This model will promote an interaction between these two extensions, allowing for the deployment of a common development platform, represented in fig. 1.

Fig 1: The X-TEC conceptual model



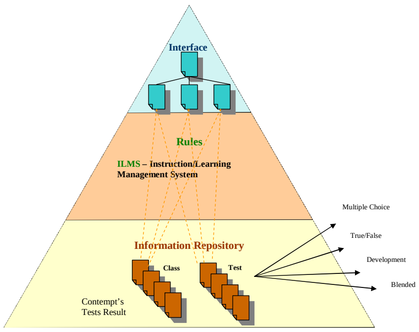
The X-TEC lifecycle is mainly supported on three major activities:
Cognitive (Knowledge) - mental skills where the brain must be used to perform intellectual tasks.
Affective (Attitude) - best described as making a commitment - just because we know something, does not mean we will act upon it.
Psychomotor (Skills) - physical skills where the body must coordinate muscular activities (some are minor, such as turning a dial with your fingers).

3. Educational System Architecture

The X-TEC model is supported by a three tiered architecture [Eckerson 95]: User Interface, Rules and Information Repository, according to fig.2.

The three tier architecture is used to provide increase performance, flexibility, maintainability, reusability and scalability, while hiding the complexity of distributed processing from end user.

Fig 2: The X-TEC architecture



1st Tier: Interface
Is related with the scenario identification, synchronous and asynchronous communication technologies and implicit and explicit messages
This tiers main actors are: Educational Software; Content Specialist's and Designers.

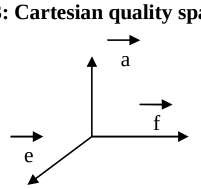
2nd Tier: Rules
Is related with the virtual abstracted organization of the content
The main actor, on the Rules tier, is: ILMS – Instruction/Learning Management System.

3rd Tier: Information Repository
It will allow all the contents, rules and interface specifications being stored on a warehousing platform.

4. Quantitative Evaluation Framework

Educational software quality is evaluated on a three dimensional space.
A dimension aggregates a set of factors. A factor is a component that represents the system performance from a particular point of view.
The dimensions of our Cartesian quality space are: Functionality (F); Efficiency (E) and Adaptability (A), represented in fig 3.

Fig 3: Cartesian quality space



For the evaluation of educational software systems based on the X_TEC model we propose a generic quantitative evaluation framework. This framework may also be applied to evaluate other Educational Software Development Models (ESDM), allowing for a direct comparison between distinct tools.
The quality q, of a given system is defined in our tri-dimensional Cartesian quality space, Q, and measured, in percentage, relatively to a hypothetically ideal system, I, represented in our quality space by the coordinates (1, 1, 1).

4.1 Quality Dimensions

The quality space, Q, aggregates, in the dimensions: Functionality; Efficiency and Adaptability, a set of factors that measure the relevant characteristics of an ESDM.
The Functionality dimension reflects the characteristics of the educational software related to its operational aspects. It aggregates four factors: feasibility, inviolability, easy of use and integrity
The Efficiency dimension aggregates four factors: data structure, programming structure, learning objects, imperfections recovery.
Through this dimension we measure the system's ability for presenting different views on the course content with minimum effort.
The Adaptability dimension is the aggregation of five factors: flexibility, modularity, reusability, scalability and maintainability. Through them we can measure to what extend the scenario and course content are efficacious – whether they are focused and able to present different instructional design theories and different learning environment in a common platform.
The quality for a given system coordinates may be obtained through the application of one of several aggregation forms. We will compute these coordinates as the average of the factors that contribute to it; the average is simple and gives the same relevance to all factors. Quality dimensions are based on the following factors: Functionality- Feasibility, Easy of use, Integrity, and Inviolability, see table 1 requirement examples of functionality dimension. Efficiency- Data Structure; Programming Structure; Learning Objects; and Imperfections recovery, see table 2 requirement examples of efficiency dimension. Adaptability- Flexibility; Modularity; Reusability; Scalability and Maintainability, see table 3 requirement examples of adaptability dimension.

table 1: requirement examples of the dimension functionality

Dimension	Factor	Requirement examples
Functionality	Feasibility	What is the cost structure of each technology? What is the unit cost per student? How quickly can courses

		be mounted with this technology? How quickly can materials be changed?
	Easy of use	What are the institutional requirements, and barriers to be removed before this educational software can be used successfully? What changes in the institution need to be made? Does the interaction this technology enables is easy to use?
	Integrity	Conceptual integrity: Does the models remain true to the concept of “objects”?
	Inviolability	
	Interactivity	What kind of interaction does this technology enable?

table 2: requirement examples of the dimension efficiency

Dimension	Factor	Requirement
Efficiency	Scenario	Implicitly and explicitly messages
	Data Structure	
	Programming Structure	
	Management Contents	
	Imperfections Recovery	
	Interface	Key screen; screen architecture

table 3: requirement examples of the dimension adaptability

Dimension	Factor	Requirement
Adaptability	Flexibility	What instructional approaches will better meet the needs of the educational environment? Is it possible for the student to choose the learning environment according to his learning profile?
	Modularity	The student is able to choose the module of his study.
	Reusability	How well the model is suited to create, as well as incorporate, reusable components into is execution.
	Scalability	Is it possible to expand?
	Maintainability	Allow to make specified modifications. Changeability (attributes of software can be modified; fault removal or environmental changed); testability (The modified software can be validated).
	Portability	Install the software in a specific environment. The student can control the place of study.

For each system being developed we will have to identify the importance of each factor to the dimension. The dimension coordinate is them computed as the weighted mean of these factors:

Dimension i = $\sum_n (p_n \times factor_n)$, $\sum_n (p_n) = 1$

and $p_n \in [0,1]$

Where:
n is the number of relevant factors for the dimension.
Each factor is evaluated by equation:

Factor n = $\frac{1}{\sum_m pr_m} \times \sum_m (pr_m \times pc_m)$

Where:
M is the number of valid requirements for the factor. pr m is the weight of the requirement m. pc m is the fulfillment percentage of the requirement m.
The dissimilarity between the system under evaluation and ideal system is measured by:

D = $\sqrt{\sum_j \left(1-\frac{Dim_j}{100}\right)^2}$

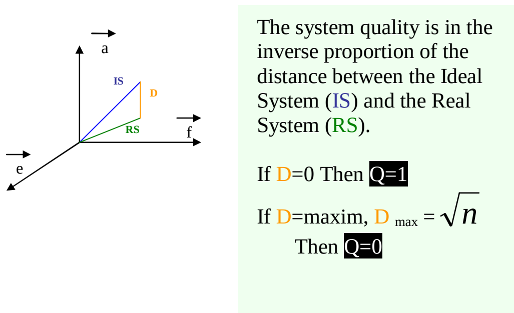
Finally the quality of the system is computed as:

Q = $1-\frac{D}{\sqrt{n}}$, Q $\in [0,1]$
or

q = $\left(1-\frac{D}{\sqrt{n}}\right)*100$, q $\in [0,100]$

The quality of a system is measured as the distance between the ideal system (projected system) and the real system (final system) see fig 4.

Fig 4: Graphic of quality of a system on QEF



The measure of the system quality is obtained from a six steps process:

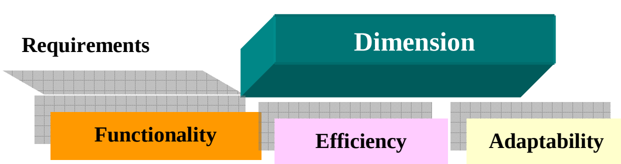
1st – Requirement classification
2nd – Factor classification
3rd – Result evaluation
4th – Dimension performance
5th – Global deviation
6th – System quality

4.1.1 Requirement classification

The ideal system has a set of requirements that indicates what the system must do fig. 5.
We start by associating weights to requirements, [0,1] based on the relevance of the requirement for that particular dimension, according to:

10 – Fundamental
8 – Very Important
6 – Important
4 – Necessary
2 – Optional
0 – Irrelevant

Fig 5: Matrix of the requirements



Pr n	Pr n	Pr n
Pr n	Pr n	Pr n
SUM()	SUM()	SUM()

4.1.2 Factor classification

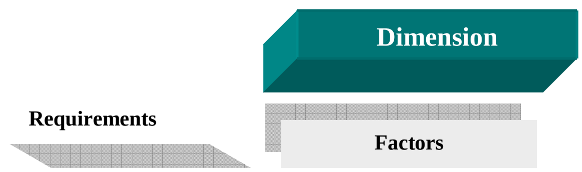
Each factor contributes to the dimension value. This contribution is represented by a real number, Pn , between 0 and 1, indicating the relevance of the factor to the dimension. The dimension value is a weighted mean the factor that contributes to that dimension.

Dimension = $\sum_n (p_n \times factor)$, $\sum_n (p_n) = 1$ and $p_n \in [0,1]$

4.1.3 Result Evaluation

It is very important to validate the requirements, so that system performance can be accurately evaluated.
The matrix in fig 6 shall be fulfilled during the evaluation process. Once it is completed the system quality is automatically computed.

Fig 6: matrix of the factors



Pcm	Pcm	Pcm
Pcm	Pcm	Pcm

Fig 2: matrix of the factors

4.1.4 Dimension Performance

The performance of a dimension is obtained through, the factors of each dimension equation.

Factor = $\sum_m (pr_m * pc_m)$

And the dimension performance is:

Dimension = $\sum_n (p_n \times factor)$,

$\sum_n (p_n) = 1$ and $p_n \in [0,1]$

4.1.5 Global Deviation

The global deviation is obtained as the Euclidean distance between our system coordinates and the ideal system, whose coordinates are (1,1,1).

D = $\sqrt{\sum_j \left(1 - \frac{Dimj}{100}\right)^2}$

4.1.6 System quality

The system quality is computed by:

$$Q = 1 - \frac{D}{\sqrt{n}}, \quad Q \in [0,1]$$

or

$$q = \left(1 - \frac{D}{\sqrt{n}}\right) * 100 \quad q \in [0,100]$$

We say that system quality is q% which means that the system is able to perform q% of its initial specifications.

5. Conclusion

In this work we propose a framework to measure quantitatively the quality of a given educational system developed with X-TEC model.
Quality evaluation frameworks, like the one we propose here, are crucial to help validating educational systems and ensure that they are adequate and follow the original specifications, before using them in the learning environment.
We are already applying X_TEC, for the development of educational software systems with our students, and using the quality evaluation framework to evaluate them. Our purpose is to realize the ability and applicability of our quantitative evaluation framework in real world solutions.
The QEF may also be applied to evaluate other Educational Software Development Models (ESDM), allowing for a direct comparison between different tools.

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