Educational Software Engineering Models: Evaluating Educational Software

Paula Escudeiro
Departamento de Engenharia Informática, Instituto Superior de Engenharia do Porto,
Rua Dr António Bernardino de Almeida, 431, 4200-072 Porto, Portugal

and

José Bidarra
Departamento de Ciências Exactas e Tecnológicas, Universidade Aberta,
Rua da Escola Politécnica, 147, 1269-147 Lisboa, Portugal

ABSTRACT

This paper presents the overall evaluation of the Quantitative Evaluation Framework (QEF) approach which has been applied in an operational teaching environment for the last six years. During this period we have evaluated the difference between educational software systems that were developed using the Techno-Didactical Extension for Instruction/Learning Based on Computer (X-TEC) model and educational software systems using other models. The X-TEC model is used in the development of educational software in order to strengthen the potential quality of e-Learning systems. We selected the QEF approach for this evaluation to highlight the strengths and limitations of the X-TEC model. We adapted the approach in a way that the essential criteria are assessed in a pre-evaluation phase which will cover the general usage requirements.
In this research project we conduct experiments with groups of students and teachers in Multimedia Information Systems classes of Oporto Polytechnic, to examine the influence of training in an instructional system design approach on their attitude to re-use this approach, and on their performances in design, using this approach.

1. INTRODUCTION

Recently new forms of teaching have appeared that require new skills from teachers in order to make effective use of the technologies that support them. Some models of e-learning have been proposed for a variety of different purposes (Harland, 1996; Finch, 1986), for example: to support course development, frequently with no reference to business models (Laurillard, 2002); to support the design process: decision making control, implementation, funding etc. (Timmers, 2000); to support the design of the teaching and learning process. (Darby, 2001).
In most cases these models are focused on understanding thus enhancing just some part of the e-learning life-cycle. They are not designed to support overall evaluation. The X-TEC (Techno-didactical Extension for Instruction Based on Computer) model proposed by Paula Escudeiro (Escudeiro & Bidarra, 2006) is specially designed to support the evaluation, within the entire e-learning life-cycle.
Effective evaluation needs led us to include a quality framework in the X_TEC model which allows for quantitative tracking of the quality of the educational system under development, at any stage of the development life cycle.
Ultimately the function of evaluation is to support the enhancement of quality and help managing risks.
There are many reasons to assess systems which are reflected in different types of evaluation schemes (Oliver 2000): Formative evaluation: provides information that allows revisions and improvements to be made; Summative (experimental) evaluation: is concerned with judgment of courses´ outcomes against a standard rather than improvement; Illuminative evaluation: is an alternative form of summative evaluation and is concerned with identifying and exploring the factors in the success of a course that are important to participants; Integrative evaluation: joins together elements from summative and illuminative evaluation; evaluation for quality assurance (additive evaluation): this can be used both for ensuring conformance and for identifying good practice.

In order to maximize the effectiveness of the evaluation in enhancing the quality of the e-learning systems we focus the development of the educational software on a particular form of evaluation which is "evaluation for action" (Harland, 1996; Finch, 1986). This type of evaluation reflects an "engineering" approach to evaluation. Its purpose is to provide information that is needed to take particular decisions (Patton, 1997).

The QEF (Quantitative Evaluation Framework) evaluates the educational software quality, developed with X-TEC based on the standard of reference ISO 9126 (Scalet *et al*, 2000). ISO 9126 is an international standard for the evaluation of software. The objective of this standard is to provide a framework for the evaluation of software quality. This standard does not provide requirements for software, but it defines a quality model which is applicable to every kind of software.

In this work we apply the QEF to the X-TEC model to evaluate any systems developed with the X-TEC model.

2. THE QEF APPROACH

This section presents the application of the QEF approach to assess the X-TEC model which has been applied in an operating teaching environment for the last 6 years.

We have developed the QEF approach to highlight the strengths and limitations of the X-TEC model. A set of requirements were chosen and validated by the teacher in order to evaluate the educational software developed by the students in a particular class on Multimedia Information Systems, in the Polytechnic Institute of Oporto, table 1, 2 and 3, represent the Educational Software Requirements established by Multimedia Information Systems

.

Dimension	Factor	Requirement examples
Functionality	Easy of use	R1: Does the student use the educational software without having to read the manuals exhaustively?
		R2: An on-line system exists to help the user overcome the difficulties?
	Content's quality	R8: Is the information well structured and does it adequately distinguish the objectives, context, results, multimedia resources...
		R9: Is the content validated? Has it no orthographic errors?
		R10: Has the alert message been checked? Are there no pervasive or negative messages and no racial or religion discrimination?
		R11: Is the content related with situations and problems of students' interests?
		R12: Are examples, simulations and graphs part of the system?

Table 1. Educational software requirements for functionality dimension

Dimension	Factor	Requirement examples
Adaptability	Versatility	R3: The educational software is easily integrated with other educational environments?
		R4: Does it allow for configuration? (level, number of users on line, language…)
		R5: Does it includes an evaluation system, during the development process?
		R18: Does it allow for new techniques and better learning?
	Pedagogical aspects	R19: Does it allow for activities that keep the curiosity and the interest of the students in the content, without provoking anxiety?
	Didactical resources	R20: Does it provide different activity types, concerning the knowledge acquisition, that allow for different forms of using the system?
		R21: Does it provide help for students as tutoring actions,

		guiding activities and reinforcements?
	Stimulates initiative and self-learning	R22: Does it allow for students' decisions concerning the tasks to carry through, the choice of study module and the study of subject matter?
	Cognitive effort of the activities	R23: Does it allow for easy memorization, interpretation, syntheses and experimentation?

Table 2. Educational software requirements for adaptability dimension

Dimension	Factor	Requirement examples
Efficiency	Audiovisual quality	R6. Is there no excess of information?
	Technical and static elements	R7: Has it a rigorous scenario design which includes title, menus, video, sound, photos, metaphor, color rules?
	Navigation and interaction	R13: Does the educational software have a good program structure that allows easy access to content and activities?
		R14-: Is the speed of communication between the program and the user (animation, presentation of contents, reading of data...) adequate?
		R15: Is the program execution efficient and with no operational errors?
		R16: Is the navigation system transparent, allowing the user to control actions?
	Originality and use of advanced technology	Has the system been developed with originality?

Table 3. Educational software requirements for efficiency dimension

The QEF framework is not restricted to measure the final quality instead it allows for the evaluation of systems quality at any moment during is lifecycle.
The fulfillment of these factors was measured at two distinct settings: on one of them X-TEC was not used by students. On the other students developed their projects with X-TEC.
The requirements were grouped in factors according to theirs characteristics, table 4.

Id	Factors
F1	Easy of use
F2	Versatility
F3	Audiovisual quality
F4	Technical elements
F5	Content quality
F6	Navigation and interaction
F7	Novelty and use of advanced technology
F8	Pedagogical aspects
F9	Didactical resources
F10	Stimulates initiative and self-learning
F11	Cognitive facilitation in activities

Table 4. Educational Software Factors

The dimensions were previously established: Functionality; Adaptability and Efficiency.
For each dimension we have a group of factors and for each factor we have a group of requirements identified by the teacher to evaluate the educational software developed by their students, as seen in fig 1.

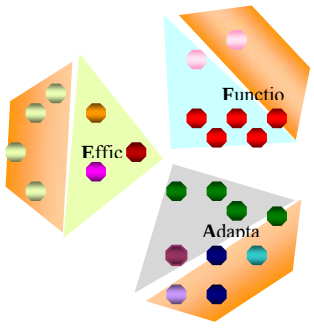
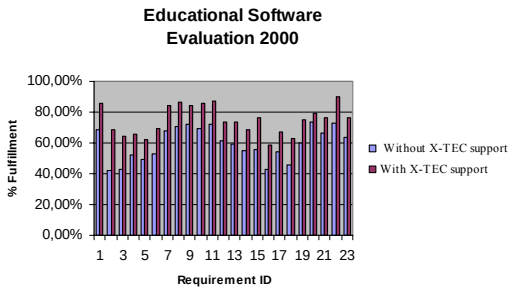


Fig 1. Relationship between Dimensions-Factors-Requirements for the evaluation of educational software developed by the students in their classes.

3. EVALUATION RESULTS

The graphics bellow shows the results of the evaluation of the educational software developed by the students under two distinct experimental settings. This evaluation matrix has been used since 2000. The QEF approach measures quality relatively to a hypothetical ideal system whose quality is assumed to be 100%.



Graphic 1. Educational software evaluation in the year 2000

The graphic 1 shows that, in the year 2000, the students development of educational software supported by X-TEC model had better evaluation results for each requirement than when they were using structured analysis and design methodologies or object oriented methodologies to support the development. This graphic shows seven requirements with a % requirement fulfilment above 80%, according to its initial specifications, and all the others requirements with a higher % of requirement fulfilment when they use the X-TEC model to their development.

In the year 2001, the students developed the educational software in the same way as in the year 2000. They made the first educational software system with structured analysis conceptual model or object oriented analysis and design methodologies to support the development.

The second educational software system development was supported by X-TEC model. As in the year before the evaluation results were much better when using this conceptual model. We notice the % requirements fulfilment has grown to 10 requirements near 80%.

In the years 2002, 2003, 2004, 2005 the student's educational software development were already based on X-TEC model.

In order to get a measure of quality on educational software systems, according QEF, we have to fulfill a matrix which represents the requirements ideal system.

In this study the requirements identified by the teacher, in the Multimedia Information's Systems class, were applied on QEF to obtain the teacher's ideal system. As we can see in the matrix below all the requirements, in the ideal system, as been fulfilled with a weight of 10, that means all the requirements has a maximum relevance for the dimension they belong.

Requirement Id	Factor Id	Ideal system requirement fulfilment	Real system req. fulfilment % year 2000
1	F1	10	68.3
2	F1	10	42.5
3	F2	10	42.5
4	F2	10	52.5
5	F2	10	49.17
6	F3	10	52.92
7	F4	10	67.5
8	F5	10	70.42
9	F5	10	72.08
10	F5	10	68.58
11	F5	10	72.5
12	F5	10	61.25
13	F6	10	59.17
14	F6	10	55
15	F6	10	55.83
16	F6	10	42.92
17	F7	10	54.28
18	F2	10	45.4
19	F8	10	60
20	F9	10	73.75
21	F9	10	66.67
22	F10	10	72.92
23	F11	10	63.33

Table 5: Matrix of educational software requirements fulfilment in ideal system and real system

We are now analyzing the evaluation of educational software developed by the students, in the year 2000, without using the X-TEC model.

According to QEF the performance of a dimension is obtained through, the factors of each dimension, and it is calculated by the following formula:

$$\text{Factor}_{n} = \frac{1}{\sum_{m} pr_m} \times \sum_{m} \left(pr_m \times pc_m \right)$$

We have now to calculate the contribution of the factor in the dimension. This contribution indicates the relevance of the factor to the dimension.

Dimension: **Functionality**

$D_{Functionality}$ = 1/20 * (10*68.3+10*42.5) + 1/50 * (10*59.17+10*55+10*55.83+10*42.92)

$D_{Functionality}$ = 55.4 + 69.2

F1; F5

Dimension: **Adaptability**

$D_{Adaptability}$=1/24*(10*42.5+10*52.5+10*49.17+10*45.4)+1/10 * (10*60) + 1/20 * (10*73.75+10*66.67) + 1/10 * (10*72.92) + 1/10 * (10*63.33)

F2; F8; F9; F10; F11

$D_{Adaptability}$ = 36.04+60+70.21+72.92+63.33

Dimension: **Efficiency**

$D_{Efficiency}$ 1/10 * (10*52.9) + 1/10*(10*67.5) + 1/40*(10*59.17+10*55+10*55.83+10*42.92) + 1/10*(10*54.28)

F3; F4; F6;

$D_{Efficiency}$ = 52.92+67.5+53.23+54.58

The next step is to obtain the global deviation (Euclidean distance between our system coordinates and the ideal system, whose coordinates are (1, 1, 1)). The global deviation is obtained by this formula:

DF = 55.4 * 0.5 + 69.2 * 0.5

Indicates the relevance of the factor to the dimension Functionality

DF = 62.3

DA=36.04*0.2+60*0.2+70.21*0.2+72.92*0.2 +63.33*0.2

Indicates the relevance of the factor to the dimension Adaptability

DA = 60.5

DE=52.92*0.25+67.5*0.25+53.23*0.25+54.58* 0.25

Indicates the relevance of the factor to the dimension Efficiency

DE = 57.1

The system quality is computed by:

D = √ ((1-62.3/100) ^2 + (1-60.5/100) ^2 + (1-57.1/100) ^2)

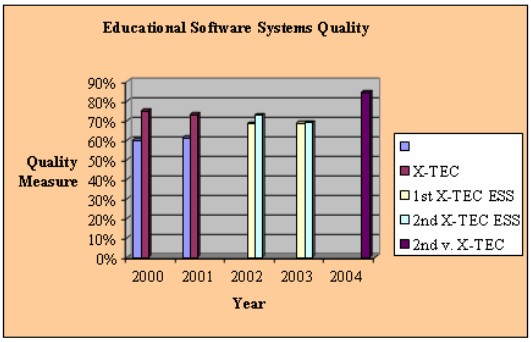
D = 0.69

Q = 1- 0.69/√ (3)

Q = 60%

We say that system quality, in the year 2000, were 60% which means that the system was able to perform 60% of its initial specifications.

Then we have to calculate the educational software systems (ESS) quality for the years 2000 (using X-Tec model), 2001(not using/using X-TEC model), 2002(using X-TEC model), 2003(using X-TEC model) and 2004(2nd version of X-TEC model) using the same process, according to the requirements specified in each year by the teacher. The graphic bellow shows the results.



Graphic 2. Educational software quality since 2000 until 2006

As we can observe the development of educational software systems using X-TEC model in the Multimedia Information Systems class has increased widely the quality of a given system.

According to these experimental results, the 2nd version of X-TEC model reflects a higher performance of the specifications in the development of educational software systems.

CONCLUSION

The design and evaluation of the learning environment will soon became an essential task in the polytechnic institutions. This will support the ongoing transitions in higher education. In what is called "new learning" there is a new trend visible in which the focus is less fixed on knowledge transmission and more on teacher's support of learning process.

The design and construction of the learning tasks will be based on conceptual models, such as the X-TEC model and the QEF, specially designed to support effective evaluation as a solid base for a renewed curriculum.

Our work, presented in this paper, leads us to believe that using X-TEC to support the design and development of learning systems improves the quality of the final product.

The final product quality was evaluated with QEF. This quality evaluation framework seems reliable and can be used to evaluate a system quality evolution trough its lifecycle.

ACKNOWLEDGEMENTS

The author would like to thank the Polytechnic Institute of Oporto and GILT (Graphics, Interaction and Learning Technologies) for making possible this work.

REFERENCES

[1] A. Dias Figueiredo (2005), Context Engineering: And is Development Research Agenda, Universidade Coimbra, 2005

[2] Allesi, S. e Trollip (1985), S. Computer Based Instruction: Methods and Development, Prentice Hall, Inc. Englewood Cliffs, New Jersey, USA, 1985

[3] Bates Tony, (2000), A. W. Tony Managing Technological Change: Strategies for College and University Leaders. San Francisco, 2000

[4] BloomBertram B. Mesia, and David R. Krathwohl, (1964), Bloom B. S. Taxonomy of Educational Objectives,: The Affective Domain & The Cognitive Domain. New York: David McKay Co Inc.

[5] Booch, (1994), G. Booch, Object Oriented Analysis and Design With Applications, Second Edition, Benjamin/Cummings, Menlo Park, Califórnia, 1994.

[6] Clark 1994, Gery, (1994), Gery, GJ Making CBT happen. Boston: Weingarten.
Clark, RE Media will never influence learning. Educational Technology Research and Development

[7] Coad and Yordon, (1991), P. Coad and E. Yourdon, OOA –Object Oriented Analysis, 2nd Edition, Prentice Hall, Englewood Cliffs, New Jersey, 1991

[8] Crossley, K. e Green (1990), Le Design des Didacticiels: Guide Pratique pour la Conception de Scénarios Pédagigiques Interactifs. ACL-Editions, Paris France 1990.

[9] Darby, M. R., Zucker, L. G., and Armstrong, J., 2002. Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology. Management Science, 48, 138-153.

[10] Eckerson (1995), Eckerson, Wayne W. "Three Tier Client/Server Architecture: Achieving Scalability, Performance, and Efficiency in Client Server Applications." Open Information Systems 10, 1 (January 1995): 3(20).

[11] Escudeiro, P.; Bidarra J., (2006), X-TEC: Techno Didactical Extension for Instruction/Learning Based on Computer – A new development model for educational software, Setúbal, Portugal, WEBIST 2006.

[12] Finch (1986) Finch, J. Research and Social Policy. Falmer.

[13] Gagné, (1996), Gagné, Robert M. and Medsker, Karen L. (1996). The Conditions of Learning Training Applications. Florida: Harcourt Brace & Company.

[14] Harland 1996 Harland, J. Evaluation as realpolitik. In Scott D & Usher R (Eds), Understanding Educational Research. Routledge.

[15] Jacobson, (1992), Jacobson, Object Oriented Systems Engineering, Addison-Wesley, 1992.

[16] Keller/Back (2004), Keller, M.; Back, A.: Blended-Learning-Projekte im Unternehmen, Learning Center der Universität St. Gallen, St. Gallen, 2004

[17] Laurillard, Diana (2002). Rethinking University Teaching, 2ª Ed., Parte II, "Analysing the Media for Learning and Teaching" (79-172). London and New York: Routledge/Falmer.

[18] Merrill, (1981), Merrill, M.D., Kowallis, T., & Wilson, B.G. Instructional design in transition. In F. Farley & N. Gordon (Eds.), Psychology and education: The state of union

[19] Minken, I., Stenseth, B. E Vavik L., (1998), Educational Software. ULTIMA-Gruppen A/S, Haden, Norway, 1998

[20] Oliver 2000, Oliver M, Evaluating online teaching and learning, Information Services and Use, vol 20 (2/3)

[21] Pressman Roger S., (2001), Pressman, Roger S. Software Engineering a Practitioner's Approach, 5 th Edition, McGraw-Hill Companies Inc, 2001

[22] Purinima Valiathan, (2005), ASTD-Linking People, Learning & Performance. Learning circuits- American Society for Training & Development

[23[Rumbaugh et al, (1991), J. Rumbaugh, M. Blaha, W. Premerlani, F. Eddy, and W. Lorensen, Object Oriented Modeling and Design, Prentice Hall, Englewood Cliffs, New Jersey, 1991.

[24] Scalet et al, 2000, ISO/IEC 9126 and 14598 integration aspects: The Second World Congress on Software Quality, Yokohama, Japan, 2000.

[25] Timmers (2000), Timmers, P.: Electronic Commerce: Strategies and Models for Business-to-Business Trading. Wiley,.

[26] Yourdon, (1998), E. Yourdon, Managing the System Life Cycle, 2nd Edition, Yourdon Press/prentice Hall, Englewood Cliffs, New Jersey, 1998.