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Evaluation of Collaborative Learning Systems

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Abstract: - Collaborative Learning is emerging as an important learning method. Computer and network supported collaborative learning systems and environments are starting to appear. In order that these systems contribute positively into the educational process, it is important to consider quality requirements. This paper presents the CLE (Collaborative Learning Evaluation), a framework for evaluating Collaborative Learning systems. It presents and analyzes three quality dimensions: educational, economical and technical. The educational dimension includes content & activities, pedagogy & abilities, interaction & communication. The economical dimension includes costs, contracts & licenses and cost-effectiveness. The technical dimension includes user interface, reliability, maintainability, performance, functionality, adaptation, connectivity and security. Designers, developers and evaluators of Collaborative Learning systems may use this framework to make appropriate decisions.

Key-Words: - collaborative learning, cooperation, evaluation, human-computer interaction, pedagogy, quality requirements, usability.

1 Introduction

Collaborative Learning (CL) has great potential in facilitating active, constructive and experiential learning. In a collaborative learning environment the learners collaborate to perform educational tasks, activities, projects, etc. Recently, many computer and network based CL systems are being developed to enhance learning [1-4]. A CL system consists of the learners' devices, the networks interconnecting them, the software that manages all activities and participants, other hardware and software resources. The CL system manages all these so that the learners achieve effective learning. The virtual room metaphor is used in [1] to develop a cooperative learning system. The virtual institute metaphor is used in [2]. Cooperative hypermedia are used to represent both shared learning spaces and shared information spaces as shared hyperdocuments. An infrastructure for collaborative lifelong learning is described in [3]. It is based on integrated collaboration functionality, transitions between different learning modes and a scalable standards-based architecture.

However, little work exists on developing a common framework for evaluating the quality of CL systems [4-11]. Quality includes the characteristics of the system that ensure its ability to satisfy the user needs. Usability and user satisfaction are extremely important for effective CL [4]. Evaluation of CL systems is needed to justify the investment and select the most appropriate ones [5]. It is important to evaluate the quality of CL systems in various contexts of use. For example, does the CL system support collaborative and active learning? Does it adapt to the learner? Is it easy to use? Is it secure? Is it cost effective?

A collaborative virtual learning environment that uses avatars in a virtual world is developed and evaluated in [6]. The evaluation is performed at four levels: pedagogical-psychological, technical-functional, organizational-economical, and social-cultural. An observation method, an inspection method, a usability design method and a hierarchical task analysis of collaboration in collaborative virtual environments are presented in [7]. A context-oriented communication model that focuses on the dialogical communication and mediation of context is described in [8]. The evaluation of a prototype shows that the concept of annotations is well received. A collaborative learning platform to support the implementation of a variety of learning environments is developed in [9]. Initial experience indicates its applicability. A web-based consultation space is evaluated by a non-deterministic qualitative, utilisation-focused approach in [10]. The student's perceptions on the usability, usefulness, group work and international collaboration of a collaborative virtual learning environment are shown in [11].

We present the CLE (Collaborative Learning Evaluation), a framework for evaluating CL systems. For the technical characteristics of the CL, we are inspired by the ISO 9126 quality standard [12]. However, we do not closely adhere to it. We extend it to best suit CL systems. In addition, we consider the educational and economical characteristics of CL. The ISO/IEC 9126 standard for software evaluation defines six software quality characteristics: Functionality, Reliability, Usability, Efficiency, Maintainability, and Portability. Each of these characteristics is further decomposed in a set of sub characteristics. So, Functionality is characterized by Suitability, Accuracy, Interoperability, Compliance and Security. Reliability is characterized by Maturity, Fault Tolerance and Recoverability. Usability is characterized by Understandability, Learnability and Operability. Efficiency is characterized by Time Behavior and Resource Utilization. Maintainability is characterized by Analyzability, Changeability, Stability and Testability. Portability is characterized by Adaptability, Installability, Conformance and Replaceability. For the technical dimension, we consider the following sub-dimensions: 1) User Interface, 2) Reliability, 3) Maintainability, 4) Performance, 5) Functionality, 6) Connectivity, 7) Security, and 8) Adaptation. For the educational dimension, we consider the following sub-dimensions: 1) Content & Activities, 2) Pedagogy & Abilities, and 3) Interaction & Communication. Finally, for the economical dimension, we consider the following sub-dimensions: 1) Costs, 2) Contracts and Licenses, and 3) Cost-Effectiveness.

2 CLE Quality Requirements

In this Section, we propose the CLE framework with the following three dimensions: A) Educational, B) Economical, and C) Technical.

2.1 Educational dimension

The Educational dimension includes the following: 1) Content & Activities, 2) Pedagogy & Abilities, and 3) Interaction & Communication (Tables 1- 2).

Content & Activities	**Pedagogy & Abilities**
Personalization	Personalization
Accuracy & Validity	Pedagogical theories
Objectivity & Bias-free	Communication
Comprehensiveness	Interpersonal & Social
Clear & Simple Presentation	Openness
Appropriateness & Suitability	Flexibility, Adaptability
Currency	Cooperation, Sharing & Caring
Stability & Durability	Leadership
Usefulness,Effectiveness	Management,Coordination
Organization& Structure	Knowledge Retention
Educator's Easiness of:	Critical Thinking
Management Planning	Creativity & Innovation
Authoring, Developing	Responsibility & Trustworthiness
Teaching	Participation, Involvement
Tutoring, Supporting	Commitment, Persistency
Exams, Assessment	Motivation
Grading	Confidence, Self-Efficacy
Reporting	
Learner's Easiness of:	
Studying & Learning	
Acting & Constructing	
Exchanging work	
Progress Report	

Table 1. Content-Activities and Pedagogy-Abilities criteria of CL systems.

2.1.1 Content & Activities

The content of the CL system should be personalized based to each learner's and educator's personal characteristics. It should be accurate, valid and bias-free presenting all points of view objectively without discriminating. It should be comprehensive and complete covering all main ideas and key points at the right quantity. Its presentation should be clear and simple with minimum cognitive overload. It should be suitable for collaborative learning, meaningful for the participants and appropriate for the expected educational outcomes. It should present the state of the art, currently accepted knowledge that will be valid for long time. It should be useful and effective for CL. Its organization and structure should be right. It should be easy, time and cost efficient for the educators to author, develop, manage and teach it, as well as to create and assign assignments, projects, exams and tests, to grade them and report on the results. Also, it should be easy, time and cost efficient for the learners to manipulate and study it, to do the assignments, projects, exams and tests, to exchange work and cooperate among themselves, to know their progress.

2.1.2 Pedagogy & Abilities

The CL system should be based on effective pedagogical theories (e.g. constructivism, active learning, collaborative learning) and should support and improve the learner's abilities. It should improve the learner's communication (written, oral, kinesthetic, etc.) abilities with the other learners and educators. It should enrich the learner's interpersonal and social abilities. It should strengthen the learner's openness, tolerance to the difference and acceptance of others' capriccio. It should enhance the learner's flexibility, adaptability, compatibility with the others as well as his/her adjustability to various situations. It should enrich the learner's cooperation, collaboration, sharing, caring and altruism. However, it should also amplify the learner's leadership, coordinating and managerial abilities. It should enhance the learner's knowledge acquisition and retention. It should enhance his/her higher order and critical thinking. It should enhance his/her creativity, innovativeness and exploration. It should strengthen his/her responsibility, trustworthiness, reliability, credibility, accountability, loyalty to others and to the CL. It should increase his/her commitment and persistency to the CL. It should enhance his/her motivation. Finally, it should augment his/her confidence and self-efficacy.

2.1.3 Interaction & Communication

The CL system should support personalized interaction and communication among the participants that are based on the individuals' characteristics. It should be easy, time and cost efficient for the participants to interact, communicate, monitor, cooperate, negotiate, argue, agree, advise, reward and penalize among themselves. It should try to achieve non-discriminating, balanced or prioritizing participation. It should establish team building, trust and cohesion. It should define clear roles and relationships among participants. It should support a large number of concurrent participants and activities. It should be easy for a participant to search and find another participant, activity or resource. A participant should be aware of all interaction, communication and activities that concern him/her and other participants who are related to her. It should provide a variety of interaction and communication tools, such as i) synchronous communication: chat, shared spaces, whiteboards, web-cast, telephony, video-conferencing, games, simulations, etc. and ii) synchronous communication: email, e-lists, newsgroups, bulletin boards, newsboards, file exchange, forums, wikis, blogs, etc. It should provide a variety of interaction and communication modes and forms, such as formal or informal, explicit or implicit, cooperation or competition, friendly or hostile, defensive or aggressive, etc. It should support efficient scheduling among activities or participants. For example, it should queue participants during a discussion or debate. It should keep synchronization and limit interference among participants or activities. It should keep the consistency of interaction and communication among participants.

Interaction & Communication
Personalization
Easiness of:
Interacting & Communicating
Participating
Monitoring
Cooperating & Competing
Confirming & Negotiating
Arguing & Agreeing
Advising & Guiding
Praising & Criticizing
Rewarding & Penalizing
Non-discriminating
Balancing
Prioritizing
Team Building, Trust, Cohesion
Clear Roles & Relationships
Number of participants
Number of concurrent activities.
Search participant or activity
Awareness
Tools & Modes Comprehensiveness
Synchronous -Asynchronous
Efficient Scheduling
Synchronization & Coordination
No interference
Consistency

Table 2. Interaction-Communication criteria of CL systems.

2.2 Economical dimension

The Economical dimension includes the following: 1) Costs, 2) Contracts & Licensing, and 3) Cost Effectiveness (Table 3).

Costs	Contracts & Licenses	Cost Effectiveness
Planning. Buying. Operating. Maintaining. Upgrading. Terminating. Health. Environmental.	Variety. Flexibility. Duration. Visibility & Awareness. Discounts. Guarantees.	Fees. Learner's Satisfaction. Learner's Learning. Cost-Effectiveness, Feasibility.

Table 3. Economical criteria of CL systems.

2.2.1 Costs

The various costs should be considered together. There are costs in planning, buying, operating, maintaining, upgrading and terminating the devices, the networks, and the CL system. There also possible health and environmental costs. Finally, the cost-effectiveness is related to the achieved learner's satisfaction, learning with respect to the fees and the costs.

2.2.2. Contracts & Licensing

The CL system should offer a large variety of contracts and licenses for using it. For example, there should be alternative contracts or licenses with respect to the number of subjects, the number of participants, the number of activities, the collaborative activities duration, the traffic, the network quality, etc. The school should either buy or lease (rent) the CL system. Each participant may pay (or not) some fees. So, the administrator and the participants should choose the most appropriate contract or license. They should be aware of the various costs and fees which should be transparent at any time. For example, the participants should be aware and know exactly the fees for every video-mail sent or received. The flexibility, duration, visibility, discounts (e.g. with respect to the number of participants, activities) and guarantees are also important parameters.

2.2.3. Cost Effectiveness

Considering on one side the costs and expenses of the CL and on the other side the learning outcomes, the learner's satisfaction, fees and other incoming parameters (e.g. reputation), the CL system should be cost-effective.

2.3. Technical dimension

The Technical dimension includes the following: 1) User Interface, 2) Reliability, 3) Maintainability, 4) Performance, 5) Functionality, 6) Adaptation, 7) Connectivity, and 8) Security (Tables 4-7).

User interface	Reliability
Easiness of use	Error Free
Quality	Error Prevention
Layout& Presentation	Error Recognition
Media	Error Recovery
Multilingualism	Stability
Interactivity	Correctness
Navigability	Consistency
Orientation & Help	Backup
Accessibility	Reputation&Guarantees

Table 4. User Interface and Reliability criteria of CL systems.

2.3.1. User Interface

The user interface should be personalized. It should be easy, time and cost efficient to understand, learn, remember and use. It should be simple and convenient to use (e.g. minimum number of clicks to find and display information, minimum number of scrolls to display information). It should facilitate communication and collaboration. It should support the learner's focus and attention, avoiding his/her distraction, boring and tiredness due to cognitive load. Its features and operation should be appropriate, convenient, meaningful, self-evident, and rational. It should be uniform and consistent. Under the same conditions similar results should be produced (e.g. messages, colors, menus). Its operation should be correct, accurate, precise and effective. Its layout, organization and structure (e.g. frames, menus, buttons) should be simple, intuitive, rational and effective. Its design should be aesthetic, attractive, pleasant and fun to use it. It should support many languages and media types (e.g. text, audio, video, immersion) of high fidelity at the right mix and position on the user interface.

It should support a variety of rich and of high quality interactivity and multimedia communication (e.g. one-to-one, one-to-many, many-to-many, synchronous, asynchronous). The interactivity and the multimedia communication should be at the right quantity at the right moment without producing cognitive overload. Its navigation should be easy, simple, intuitive and rational. There should be alternative ways of navigation with proper number of levels. It should offer many navigation facilities (e.g. sitemap, next, previous, home, exit, undo, redo, shortcuts, history, save, print). It should provide quality orientation and help (e.g. documentation dictionaries, FAQ, search engine) in a consistent way. The responses to any learner's action should be immediate and effective. It should consider learners with disabilities and do not discriminate. It should treat all fairly.

2.3.2. Reliability

Reliability is related to the capability of the CL to maintain its level of performance under stated conditions for a stated period of time. The CL system should be error-free. It should prevent errors that may occur, for example measurement errors. It should be easy and fast to be monitored and tested. If an error or fault happens, it should recognize its existence and its source. It should also make correct diagnosis of the error. The error should be easily repaired by the system or by external intervention with minimum effort and resources at the minimum time. No data or other useful resources should be lost in case of error. The repair should be transparent to the learners. No data discrepancies should occur due to hardware faults (e.g. power off, communication disconnection). The duration and the cost of the interruption should be minimal. The CL should handle any unexpected case and should resist to malicious attacks. It should not be stacked in a deadlock situation. Its operation should be stable and consistent with minimal transient phenomena. It should always be available.

Its operation should be correct and accurate. It should do what is supposed to do, for example alerting learners about deadlines. Its operation should be consistent and similar states should be treated similarly. It should keep on back of all data, interactions, communications, achievements, statistics, etc. The perceived reliability of the system increases with the reputation and the brand name of the manufacturer, as well as with awards, certifications and guarantees that are given to it.

2.3.3. Maintainability

Maintainability is related to the effort needed to maintain the CL and make specific modifications. Initially, the installation of the CL should be easy and fast. The CL should need minimal effort and time to maintain its efficient operation. In case of changes in its scope and operation, its reconfiguration should be easy, unproblematic and fast. In case of faults, the repair or replace of the faulty parts should be fast and easy. It should be easy and fast to be revised and upgraded. Its integrity, resistance and survival from attacks should be guaranteed. Its efficient operation should be supported by the manufacturer. The guarantees should be for long time and take care of any possible case.

Maintainability	Performance
Installability	Responsiveness
Easiness of Maintainance	Memory
Reconfigurability	requirements
Replaceability	Input & Output
Survivablity	Resource
Upgradeability	Utilization
Supportability	Effectiveness

Table 5. Maintainability and Performance criteria of CL systems.

2.3.4. Performance

Performance is related to the achieved performance and efficiency of the CL. The CL system should operate fast enough to facilitate collaboration. The communication bandwidth (both for uploading and downloading) should be high enough to support any possible communication. The memory capacity should be large enough to store all possible data, transactions, communications, etc. The quality and the fidelity of the input (e.g. camera, handwritten recognizer, speech recognizer) and output (e.g. screen, speakers) should be appropriate. For example, the quality of the displayed, stored and transmitted images should be the best possible given the constraints (bandwidth, delay etc.). So, the camera and screen resolution, the screen size, the ergonomic keyboard are important factors. The energy consumption should be small. Finally, the effectiveness and efficiency of the system should be high.

2.3.5. Functionality

Functionality is related to the available functions, features, tools, and applications in the CL. Examples of tools include: editor, drawing, audio recorder, photo camera, video recorder, fingerprint reader, handwriting recognition, speech recognition, face recognition, multimedia processing, etc. Examples of features and applications include: multimedia mail, alerting and reminding, chat, telephony, videoconference, etc. These features and applications should be of high quality, simple, self-explanatory, intuitive and rational to use them. Each feature or application should function autonomously and be self-contained. There should be no need for extra plug-ins. Multiple features and applications should function concurrently synchronized with no interference among them. The technology used to implement the system should be not only current and innovative, but also mature and stable.

Functionality	Connectivity
Comprehensiveness Quality Simplicity Usefulness Suitability Timeliness Synchronization Autonomy Innovativeness Maturity	Openness Standards Compliance Interoperability Reusability Portability Transparency Scalability Comprehensiveness

Table 6. Functionality and Connectivity criteria of CL systems.

2.3.6. Connectivity

Connectivity is related to the ability of the CL system to be connected to other software and hardware systems. The CL system should provide as much connectivity (inside and outside of the system) as possible. Tools, applications, resources, learners and teachers should be smoothly interconnected. It should follow open architectures, comply with international standards and be compatible to as many software and hardware devices as possible. It should easily import and export data, transactions, communications, statistics, etc. All parts should be seamlessly integrated to construct the whole CL. The integration of the parts should be transparent to the learner. All interconnections should be done in harmony with minimum learner's effort. Also, parts of the CL system may be reused by multiple systems. Also, it should be easy and fast to connect or disconnect as many concurrent activities and participants as possible. It should support multiple platforms, databases, collaboration types, multimedia format, etc. Finally, it should be autonomous not required additional plug-ins.

2.3.7. Security

CL should support current, updated security technologies (e.g. firewalls, access control, authorization, authentication, certification, encryption, cryptography, tunneling, anti-virus, anti-spam, anti-spy) to protect the interactions, communications, data, transactions, results, etc. It should protect both the storage and the communications. It should support multiple levels of security for different learners and resources. It should prevent unauthorized access to resources, tools, data or unauthorized communications and collaboration. It should support the learner's confidentiality, anonymity, privacy and trust. The learner should have control of what personal information should be available to others. All data, activities, decisions and applications that concern a learner should be visible and available to him/her whenever he/she requests them. For example, there should be no secret monitoring and recording of the learner's transactions. High prestige security organizations should certify and guarantee its security.

Security	Adaptation
Completeness Levels Confidentiality & Privacy Trust	Control Comprehensiveness Transparency Correctness Usefulness Timeliness Consistency Flexibility Prioritization

Table 7. Security and Adaptation criteria of CL systems.

2.3.8. Adaptation

The CL system should adapt its educational parameters (e.g. content, activities, presentation, communication), its technological parameters (e.g. user interface, security), and its economical parameters to the learner and the teacher. It should be personalized. For example, it should adapt the communication to the learner according to his/her network connection. It should adapt the content to the screen size. It should adapt the resolution of an image to the available transmission bandwidth. The adaptations should be transparent to the learner. They should be correct, accurate, precise, and error free. They should be useful, appropriate and effective. They should also be timely. They should be consistent and uniform, similar results should appear for similar reasons. They should be flexible and adjustable, i.e. if an exact match cannot be found an approximation should be given. Also, there should be prioritization among the parameters importance in case of constraints or conflicts.

3 Conclusion

The learner is at the core of the Collaborative Learning. Every effort should be made to support the learner. The learner should participate in the collaborative activities being satisfied and using the resources efficiently. We provide the CLE framework on user requirements of Collaborative Learning. Designers, developers and evaluators of Collaborative Learning systems should consider educational, economical and technical characteristics. We analyze these dimensions and suggest guidelines for design, development and evaluation of Collaborative Learning systems.

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