An E-Assessment Website to Implement Hierarchical Aggregate Assessment

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Abstract—This paper describes a Web server implementation of the hierarchical aggregate assessment process in the field of education. This process describes itself as a field of teamwork assessment where teams can have multiple levels of hierarchy and supervision. This process is applied everywhere and is part of the management, education, assessment and computer science fields. The E-Assessment website named "Cluster" records in its database the students, the course material, the teams and the hierarchical relationships between the students. For the present research, the hierarchical relationships are team member, team leader and group administrator appointments. The group administrators have the responsibility to supervise team leaders. The experimentation of the application has been performed by high school students in geology courses and Canadian army cadets for navigation patrols in teams. This research extends the work of Nance that uses a hierarchical aggregation process similar as the one implemented in the "Cluster" application.

Keywords—E-Learning, E-Assessment, Teamwork Assessment, Hierarchical Aggregate Assessment.

I. INTRODUCTION

A. General

THE process of hierarchical aggregate assessment is applied everywhere where the teams have multiple levels of hierarchy. This process can be performed manually or automatically by computers with management information systems (MIS). This process finds its origins into the management field where it has been performed since the humanity worked in teams. This process has surely been performed by Julius Caesar's generals to assess the fighting power of the Roman army and the ability of their officers to lead the troops in battle.

B. Object

The object of the actual research is to perform the

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hierarchical aggregate assessment process automatically by computer. With the Internet and mobile technologies (WIFI), teamwork can be performed over the Internet and collaborative work could be implemented through the team members. The "Cluster" Internet application was developed with the Research and Development (R & D) methodology in education and is residing at the Internet address http://eval.uqam.ca/cluster/.

C. Field

The hierarchical aggregate assessment process has always been performed everywhere through ages by the humanity. Even though, the field of teamwork assessment has been defined many years ago, nobody took care of defining a particular case of the teamwork assessment where the team members have many levels of hierarchy. The domain of the hierarchical aggregate process is situated primarily in the field of management and its computerization also situates this process in the computer science field. However, the present research wants to situate also this process in the education field because some courses or complex assessment tasks can also be performed in teams that could have multiple levels of hierarchy. The "Cluster" Internet application is a complex assessment tasks presentation engine in collaborative mode for learning tasks in authentic context. This paper wants to define formally the field of hierarchical aggregate assessment and also wants that this field could be accepted and recognized by the scientific community.

D. Paper Organization

This paper will first define the problematics and the theoretical background of hierarchical aggregate assessment field. This paper will after describe the implementation of the hierarchical aggregate process with the Research and Development (R & D) methodology in the field of education with the "Cluster" Internet software application. This paper will finally show and discuss the results of the experimentation with High School students and Canadian army cadets. Further work and a short conclusion of the actual research will also be mentioned.

II. PROBLEMATICS

A. General

Until today, no scientist or scholar in the fields of management, computer science, education, assessment and evaluation has defined a name to describe the multiple levels teamwork assessment process that is applied everywhere and existed forever. This process executes itself where teams can

have multiple levels of hierarchy and supervision. The actual research described in this paper will change that and define this complex process as "hierarchical aggregate assessment".

B. Teamwork Assessment

The problematics underlying the automation of the teamwork assessment process with multiple levels of hierarchy resides in the implementation of an Internet software application that is a pedagogical product named "Cluster" developed in the present research. The hierarchical aggregate assessment process is the theory induced by the research and development process for the implementation of teamwork assessment with multiple levels of hierarchy, as shown in Fig. 1.
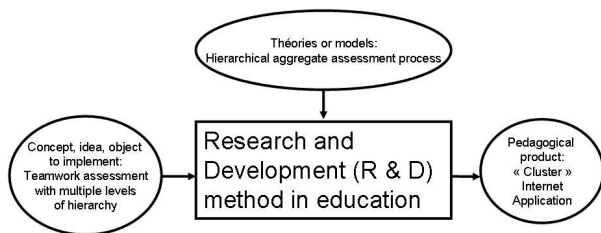

Fig. 1 Hierarchical aggregate assessment in the field of learning assessment

The hierarchical aggregate assessment theory situates itself as a subfield of teamwork assessment that is included in the educational domain, as shown in Fig. 2.
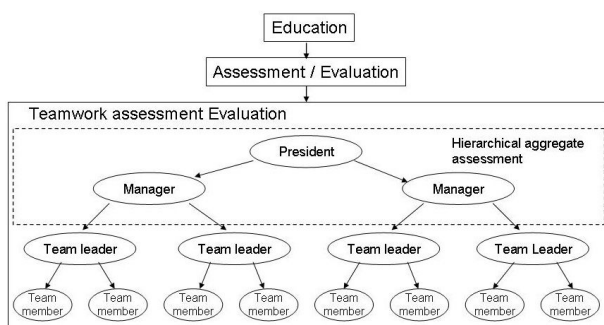

Fig. 2 The field of hierarchical aggregate assessment

Many work and research have been done in the assessment field concerning teamwork assessment. In all the work, papers and literature produced, authors as Sugrue, Seger, Kerridge, Sloane & Deane [31], Volkov & Volkov [34], Baker & Salas [2], Zaccaro, Mumford, Connelly, Marks & Gilbert [44], MacMillan, Paley, Entin & Entin [19], Furnahm, Steele & Pendelton [9], Freeman & McKenzie [7], [8], Ritchie & Cameron [29] and Lurie, Schultz & Lamanna [17] have stated theories and process concerning the dynamic of teamwork with only one level of hierarchy that concerns one team leader directing or supervising one or many team members. Until now, very few researchers or authors in the field of teamwork assessment produced research in the field of teamwork assessment with multiple levels of hierarchy.

The process of hierarchical aggregate assessment groups team members in teams with multiple levels of hierarchy where team members are appointed president, manager, team leader and team member. The structure of the teams is in the shape of a pyramid or an inverted tree representing a hierarchical organizational chart where each branch is an aggregate of team members. The hierarchical aggregation process represents the process of grouping the students in a hierarchical structure and after that, the assessment is processed for each team member or each leaf of the tree. The "Cluster" application has this organizational structure implemented in its MySQL database and can perform an assessment procedure for each node of the tree. So in the same assessment task, the application can assess different objectives, skills, knowledge and abilities. This functionality has not been implemented in the other E-Learning application as Moodle [22], Blackboard [3] and WebCT [35]. Hence, this domain specificity is establishing the basement of the actual research problematics, as shown in Fig. 3.
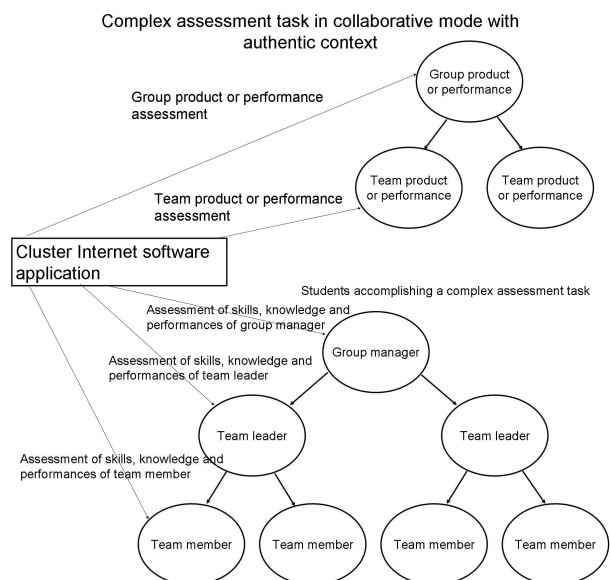

Fig. 3 Hierarchical aggregate assessment process for different skills

C. Available Computer Internet Applications

The actual commercially available E-Learning and E-Assessment Internet applications as Moodle [22], Blackboard [3], and WebCT [35] can implement collaborative learning over the Internet with virtual classrooms where a student can be a member of one or many groups an can attend one or many classes. These applications also have basic examination capabilities as homework file upload to be submitted to the teacher and multiple choice questions banks. However, none of these applications is able to aggregate or group students in teams with multiple levels of hierarchy to perform complex teamwork assessment tasks [7], [8]. The "Cluster" application data structure is designed to record the tree data structure that holds the multiple levels hierarchical relationships that links team members together while Moodle [22], Blackboard [3]

and WebCT [35] have the data structure to implement virtual classrooms but does not have the data structure to implement multiple levels of hierarchy.

III. THEORETICAL BACKGROUND

A. General

The actual research concerns the implementation of the "Cluster" E-Assessment Internet application that is a complex assessment tasks presentation engine in collaborative mode with an authentic context. This application is therefore based on the theoretical foundations of (1) complex assessment tasks stated by Louis & Bernard [17] and Tardif [33], (2) authentic assessment stated by Palm [25], Louis & Bernard [16], Wiggins [36]-[39]; Hart [12]; Allal [1] and Rennert-Ariev [27], (3) teamwork assessment stated by Baker & Salas [2] and Marin-Garcia & Lloret [20], (4) collaborative work assessment stated by Swan, Shen & Hiltz [32], Volkov & Volkov [34], Boud, Cohen & Sampson [4], MacDonald [18], Swan, Shen &Hiltz [32], and Worcester Polytechnic Institute [43], (5) assessment grids stated by Duraham, Knight & Locke [6] and Marin-Garcia & Lloret [20]; and also (6) self assessment and peers assessment stated by Lingard [14], Goldfinch [10], Goldfinch & Raeside [11] and Northrup & Northrup [24].

B. Hierarchical Aggregate Assessment Process Definition

The hierarchical aggregate assessment process defines itself generally as a subfield of teamwork assessment where teams can have multiple levels of hierarchy and supervision. In the domain of education, the hierarchical aggregate assessment of learning defines itself as a subfield of teamwork assessment where teams can have multiple levels of hierarchy and supervision where team leaders (that could be students) are assessed by one or many team managers (that could be other students or teachers) where teams can have multiple levels of hierarchy and supervision.

C. Background Research and Previous Work

The actual research project finds its previous work in other research and distance teamwork assessment software applications that were developed with a Research and Development (R & D) methodology. These applications are SPARK developed by Freeman & McKenzie [7], [8] and Willey & Freeman [41], [42], MLE developed by Marshall-Mies, Fleischman, Martin, Zaccaro, Baughman & McGee [21], MEGA CODE developed by Kaye & Mancini, [13] and the closest research related to the actual research project that is an Internet collaborative work management application developed by Nance [23].

SPARK [7], [8], [41], [42] is a distance assessment system that computes the results of self assessment grids and peers assessment grids to determine team members final scores on engineering project courses and to detect team members that haven't worked well in team and gave a low performance in their teamwork by letting other team members do their work.

MLE [21] is an application that predicts and assesses leadership potential with complex assessment tasks that are

cases and scenarios resolution.

MEGA CODE [13] is a software application that is a cardiac arrest simulator. This application is used to assess performances of intern physicians and nurses that are part of cardiac arrest resuscitation teams.

The Internet collaborative work management application developed by Nance [23] uses a hierarchical aggregate process similar to the "Cluster" application. Nance's [23] work consists in the implementation of an Internet collaborative work application designed for projects and teamwork management used by students in engineering and computer sciences faculties. This application is able to group students in teams with multiple levels of hierarchy and supervision that includes team leaders or project leaders (Bosses) and project administrators (Bosses of Bosses[BOB]) that supervises team leaders for project in engineering and computer science domains.

IV. METHODOLOGY

A. Methodological Choice and Design

The actual research project consists at the implementation of the hierarchical aggregate process with an Internet software application named "Cluster". Richey & Nelson [28] stated that the development of software to be used as educational tools is part of a Research and Development (R & D) methodology so the development of the "Cluster" Internet E-Assessment application to be used by students and teachers will place the actual research into the Research and Development (R & D) methodology paradigm.

The research and development methodology is similar to the engineering development techniques to produce durable and consumable goods. The Research and Development methodology is an iterative process that includes seven stages that are (1) preliminary analysis, (2) prototype design and realization, (3) testing phase, (4) evaluation, revision and correction, (5) publication of results, (6) distribution; and (7) marketing as stated by Loiselle [15]. If the product shows some defects at the later phases of the process as evaluation, revision and correction, publication of results, distribution; and marketing, the process returns to the analysis phase to find a solution to correct the defects. The first functional tests or Alpha tests were made by the authors of this paper to ensure that the application was ready to be used by teachers and students. After that, Beta tests were first made by Mrs. Dalila Sebkhi during her practical teaching internship and after other Beta tests were done to implement distance learning with Canadian army cadets for distance cartography courses on map navigation patrols in teams.

B. Experimentation the "Cluster" Internet Application with High School Students

The "Cluster" application was first tested with students during teaching internship III and IV of Mrs. Dalila Sebkhi that were part of the bachelor in education curriculum of the UQÀM (Université du Québec À Montréal) university. The application was used in teaching internship III as a pedagogical tool to support learning for sciences and

technology classes in the context of the second high school year at "École secondaire La Voie" High School of "Commission Scolaire de Montréal (CSDM) School Board.

The experimentation subjects consisted of 113 high school second year students divided in four classes. The course studied was a geology course that includes chapters about solar system, land relief, rock and minerals. The course material was converted in electronic format and placed into the "Cluster" Internet application so that the students could refer and study the course material at home after classes. This experimentation used only qualitative methods and was based on the observations of the students using the application. Mrs. Sebkhi also wanted to use the application in her teaching internship IV with 118 students divided in four classes in the context of the fifth high school year at "École secondaire St-Luc" that is also in "Commission Scolaire de Montréal (CSDM) School Board for teaching thermodynamics courses. Unfortunately, the school board refused the use of the application in internship IV because of resistance to change and the too large amount of time that would be needed for students to learn how to use the "Cluster" application proficiently.

C. Experimentation of the "Cluster" Application with Canadian Army Cadets

The "Cluster" application was also tested by Canadian army cadets with an experimentation group of 27 persons and a control group of 12 persons. All of the experimentation subjects had an average age of 14 years old. All of the experimentation population came from two cadets corps located in the Province of Québec situated in Canada.

The two groups used the application to learn map navigation patrol in small teams in a cartography course. The experimentation group came from the army cadet unit "Corps de cadets 2567 Dunkerque" from the city of Laval and the experimentation group came from the army cadet unit "Corps de cadets 2595 de St-Jean d'Iberville" from the city of St-Jean d'Iberville.

The course given was a cartography course on navigation with the map that include chapters on the types of maps, the information on the map, conventional signs, contour lines and also four figures, six figures and eight figures coordinates. The course material was converted in electronic format and placed into the Internet application. The navigation course was divided in two parts: a theoretical part where students learn the course material and a practical part where students had to do patrols in the field with the maps between two eight figures coordinates given by the experimenter. The control group had to study the theoretical part of the course the traditional way in presence in a classroom with a teacher while the control group students had to learn the course material at home with the "Cluster" Internet application. Both groups had to do the practical part in the field to prove the validity of learning.

The experimentation used quantitative research methods to determine the amount of learning produced by the "Cluster" application and also the level of user friendliness of the application that was determined by the QUIS (*Questionnaire for User Interaction Satisfaction*) questionnaire [5], [26], [30], [40].

The quantitative instruments used in the experimentation were (1) preliminary knowledge test, (2) final knowledge test, (3) self assessment grid, (4) peers assessment grid, (5) post-exercise report, (6) QUIS questionnaire and (7) end of course modules test. Formative assessment is given by the students with the self and peers assessment grids while the summative assessment is given by the five end-of-module tests and the marks given by the teacher or the assessor for the practical part of the course that is done in teams and consisting of map navigation patrols. The preliminary and final knowledge test scores are not included in the map navigation course and are only use for research purpose to determine the increase of knowledge for the experimentation and control groups.

The course curriculum for a course candidate was (1) to write the preliminary knowledge test, (2) to learn the five course module that weighs for 50% of the final mark in class for the control group and with the "Cluster" application for the experimentation group. There is one test at the end of each module to confirm the learning and to accumulate the first 50% of the final mark; (3) perform three map navigation patrols in teams where the course candidates are appointed team member, team leader or team manager that supervises team leaders. After each patrol, course candidates have to fill self assessment grids and peers assessment grids. The practical part of the course also weighs 50% of the final mark and is given to the students by the teacher or the assessor based on his observation of the candidate's performance and the comments given by the self and peers assessment grids regarding this candidate; and (4) write the final knowledge test.

V. RESULTS

A. Hierarchical Aggregate Process

The actual research project wants the term "Hierarchical aggregate assessment" to be accepted and recognized by the entire scientific community. This process is a subfield of teamwork assessment where teams can have multiple levels of hierarchy and supervision

B. "Cluster" Internet E-Assessment Application

The "Cluster" Internet E-Assessment application is a complex assessment task presentation engine in collaborative mode with authentic context. The application is developed in PHP language supported by a MySQL database. The "Cluster" application preliminary analysis and functional analysis was done by the CDAME research group. The implementation of the application in PHP and the design of the MySQL database were done by Frederick Fortin, information systems analyst and programmer for the LabMecas research group. The "Cluster" application software architecture is shown in Fig. 4.
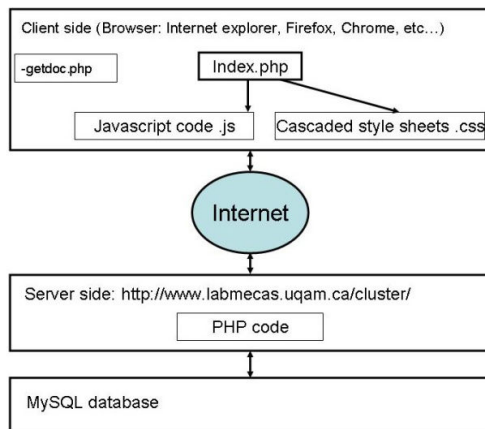
Fig. 4 Cluster application software architecture

The Internet application database is able to manage the students, the course material, the teams and the hierarchical relations between the team members that could have multiple levels. In the data structure, a course is composed of modules and modules are composed of tasks. The "Cluster" application database architecture is shown in Fig. 5.
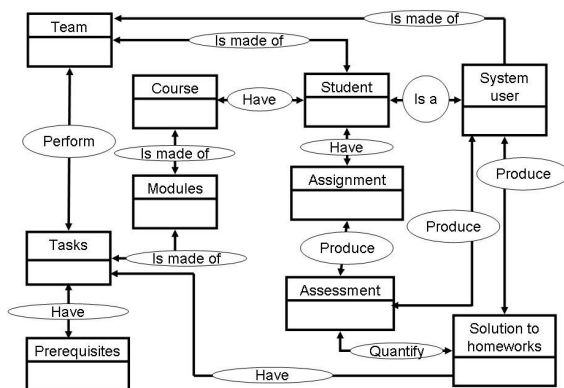

Fig. 5 Cluster application database architecture

The application has two mutually exclusive modes, the student mode and the administrator mode. The mode is determined at the login where the application recognizes if the username belongs to an administrator or a student. The "Cluster" application login and splash page are shown in Fig. 6.
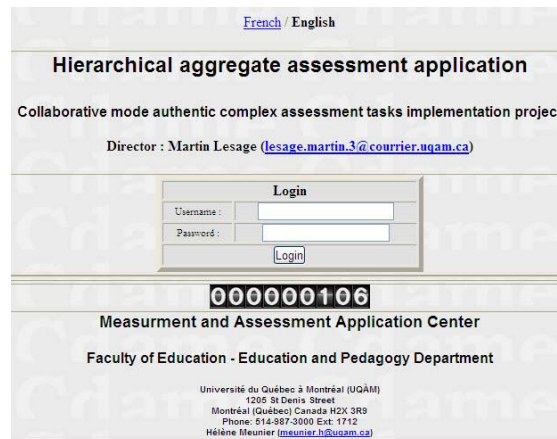

Fig. 6 The Cluster application login and splash page

The student mode is only used by the students or the course candidates. The student mode allows the student (1) to study course material, (2) to consult the curriculum record sheet to know his progression into the coursed modules, (3) to write HTML exams, (4) to submit homeworks, (5) to be part of a of a team for a teamwork assessment task; (6) and to perform self and peers assessment.

Once the student is logged in, he can choose the course that he wants to study with a menu. After the student has selected the course he wanted to study, the application drop down menu user interface appears as shown in Fig. 7.
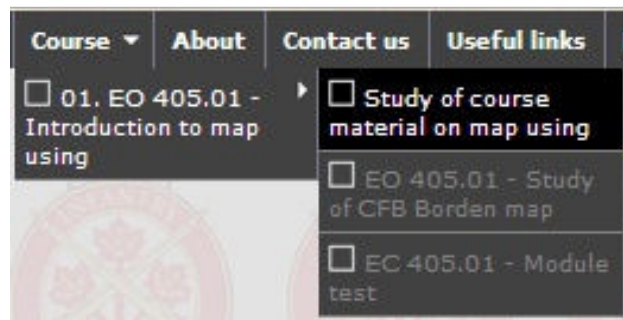

Fig. 7 Application drop down menu

The student is now able to study course material and the application displays the course material to the student that can read it and save it for further revision. The student can consult at any time the curriculum record sheet that shows the progression of the students into the course modules. The students will have individual assessment and teamwork assessment. Individual assessment will be done by HTML auto correcting objective questionnaires and homeworks to submit. Student's homeworks will be submitted by a regular file uploading form shown in Fig. 8.

Fig. 8 Homework uploading form

When the student is performing a teamwork assessment task, the student has to fill self and peers assessment forms. Self and peers assessment forms could have different assessment criteria depending of the hierarchical position of the assessed student whether he is a team member, a team leader or a team manager. These forms are similar and shown in Fig. 9.

Fig. 9 Peers and self assessment forms

The administrator mode is used by the system administrator, the teachers, the assessors and E-learning course developers to (1) manage students database, (2) manage course material database, (3) mark homework, (4) assess student performance in teams, (5) group students in teams; and (6) appoint students as team members, team leaders and course managers to implement the hierarchical aggregation tree structure and the multiple levels of hierarchy between students. The administrator mode and the student mode are mutually exclusive modes. So the system doesn't allow an administrator to be member of a course and to study course material and also doesn't allow a student to modify the student database and the course material database. A student also can't mark homeworks and teamwork tasks.

The student database management form allows the teacher or the assessor to create a student record and modify the information about a student. The course management database form allows the teacher or the assessor to create course modules and modify the course material. The teacher or the assessor can mark homeworks and write remarks about the student's performance with the homework assessment form. This form is only used by the teacher or the assessor for summative assessment to give marks on uploaded student's homeworks. The teacher or the assessor can mark the student performance in teams with the teamwork marking form shown in Fig. 10 that is the same form used by the students to write formative self assessment and peers assessment. This form is therefore used for summative assessment to mark student's performance in teams and for formative assessment by students for self and peers assessment.

Fig. 10 Teamwork marking form

The teacher or the assessor marks the student by the observation of its performance in the team regarding their hierarchical appointment as team member, team leader and course administrator. The assessment criteria are different for each hierarchical appointment. This functionality is a direct implementation of the problematic regarding multiple levels of hierarchy. This functionality doesn't exist in Moodle [22], WebCT [35], and Blackboard [3].

To determine his final mark, the teacher or the assessor can read the student's self assessment and all the formative assessment he obtained given by the student's teammates that have filled a peer's assessment form about this student.

The final course score in given by (1) the sums of the marks for the modules performed individually and that had an HTML

self correcting test or a homework to download plus (2) an overall mark given by the teacher or the assessor to the student for all the tasks he performed in teams.

Finally, the application possess an aggregation function that groups students in teams and appoint students as team member, team leader and course manager to implement the hierarchical aggregation tree structure and the multiple levels of hierarchy between students.

This functionality is another issue of the problematic regarding multiple levels of hierarchy that doesn't exist in Moodle [22], WebCT [35], and Blackboard [3]. The aggregation process allows the teacher or the assessor to group the students in teams and appoint them team members, team leaders and course managers. The aggregation form initiates the aggregation process and builds the multiple levels hierarchical structure that is stored in the application MySQL database.

C. Experimentation on High School Students

The experimentation on high school students done by Mrs. Dalila Sebkhi was the first beta test experimentation over a large sample of over 100 students. The application was used as a support for the teaching of geology courses. The results were purely qualitative and based on observations made by Mrs. Sebkhi while students were using the "Cluster" application. Many "Cluster" application users and some administrators of the school board stated that the application was too rigid for 12 to 16 years old teenagers and its interface lacked of user friendliness causing resistance to change.

The young users wanted more use of multimedia and movies so that the course would more look like a video game with avatars instead of a drop down menu interface. For some students, the use of the application went straight through and the students experienced no problems and went through all the course modules and exams placed in the application.

Other users experienced different problems as (1) resistance to change by students and teachers, (2) loosing usernames and passwords, (3) answering HTML exams, (4) getting lost with the interface navigation while studying course material, (5) design flaw in the interface denying user to go backwards into the course previous sections if a module is not understood; and (6) the needs for course administrators to keep track of the progression into the course modules and exams for a large number of students.

To overcome these problems, Mrs. Sebkhi asked four modifications to be done to the software that were implemented a few months after her teaching internship III. The first was the addition of a field in the database to identify the group or the class of the student so that the entire student database could be divided in classes or groups. The second modification consists of the implementation of a return button allowing the student to return to the previous course chapter or module. The third modification consists of the implementation of a curriculum record sheet access form for each student allowing the course administrator to consult the student's curriculum record sheet that indicates his progression through course modules without logging in the student's account. The

fourth modification consists of the implementation of a panorama representing a matrix that indicates the progression through course modules and exams for all of the students in the class.

D. Experimentation on Canadian army cadets

The experimentation results of the "Cluster" Internet E-Assessment application on Canadian army cadets are shown in Table I.

TABLE I
CLUSTER INTERNET E-ASSESSMENT EXPERIMENTATION WITH ARMY CADETS

	Experimentation group	Control Group
Population	27	12
Preliminary knowledge test	12,81%	7%
Final knowledge test	63,40%	55%
Average score on cartography course	83,45%	66,15%
Knowledge augmentation	50,59%	48%
Number of candidates that has succeeded the course	6	10
Students that abandoned the course	21	2
Success rate	22%	83%
QUIS Questionnaire	Liked: - User friendliness Not liked: 1)Feedback 2)Terminology 3)Resistance to change	

VI. DISCUSSION

The actual research produces three results: (1) the hierarchical aggregate assessment theory, (2) the "Cluster" Internet application; and (3) some data, results and conclusion about the experimentation of the "Cluster" application. The hierarchical aggregate assessment theory is now submitted to the scientific community. The "Cluster" application has been modified as explained in the "Results" section and is now fully operational. This application is now used by Canadian army cadets for the distance learning of cartography, instruction techniques and general military knowledge. The results concerning the experimentation with the Canadian army cadets showed that the knowledge augmentation produced by the "Cluster" application was 50.59% that is almost the same as the augmentation produced by traditional teaching methods in class that is of 48%. This could be explained by the Clark [45] – Kozma [46] debate where Clark [45] states that the Medias are only a vehicle that delivers knowledge.

However the success rate for the learning of cartography with the "Cluster" application is only of 22% compared to the learning of the cartography in class that is of 83%. The 22% success rate for the E-Learning could be explained by some of the main E-Leaning disadvantages in general that is the places the student alone to learn with no teacher in presence to help him. The E-Learning student misses often the dynamic of the class where he could be with his classmates and helped by the teacher.

VII. Conclusion

The actual research wants the term "Hierarchical aggregate assessment" to be accepted and recognized by the entire scientific community. This process has been used forever everywhere and no scientific or scholar has placed a term to define it. This is now done with the actual research. Actual work has been done to implement this process in the fields of education, assessment and computer science. Future work by the research team will be first done with (1) the improvement of the user interface on the items of feedback, terminology and resistance to change, (2) the implementation of the hierarchical aggregate assessment process in the field of management; and (3) determination of the influence of the "Cluster" application on knowledge augmentation, user satisfaction and user retention.

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