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Dynamic Characterization of Collaborative Objects in an ICT-based Environment for Collaborative Learning and Research

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Abstract

This research work characterizes the objects in an ICT-based Environment for Collaborative Learning and Research. It presents a conceptual structure for a collaborative space and its constituent elements. It then proposed a classification for the objects in a collaborative space. Moreover, a model for the representation of objects was proposed and the dependency of objects on some other components of collaborative environment is identified.

Keywords- Collaborative space, ICT-based environment, Object representation, Object classifications, Objects dependency

I INTRODUCTION

In any collaborative environment, there are chains of activities which are facilitated by interactions. Interactions among collaborating actors involve the use of objects. Knowledge could be tacit (unspoken) or explicit (expressed or written), (Harry Collins, 2010). Harry Collins further clarified that "Knowledge cannot be found in the absence of the activities of humans".

Better still, an ICT-based environment for collaboration facilitates dematerialization of objects from hardcopy to different electronic format. This paper beams search-light on the characterization of objects created, used or managed in an ICT-based environment for collaboration. Objects are produced during collaboration examples of which are documents in versions, annotations and bookmarks from which knowledge could be mined. This therefore buttresses the fact that objects' importance cannot be over-emphasized in interactions within activities running in a collaborative environment.

II RELATED WORKS

According to www.teaching.uncc.edu (2017), one of the most widely used ways of organizing levels of expertise is according to Bloom's Taxonomy of Educational Objectives, (Bloom et al. 1994; Gronlund, 1991; Krathwohl et al., 1956). Bloom's Taxonomy (Tables 2.1-2.3) uses a multi-tiered scale to express the level of expertise required to achieve each measurable student outcome. Organizing measurable student outcomes in this way will allow us to select appropriate classroom assessment techniques for the course. There are three taxonomies. Which of the three to use for a given measurable student outcome depends upon the original goal to which the measurable student outcome is connected. There are knowledge-based goals, skills-based goals, and affective goals (affective: values, attitudes, and interests); accordingly, there is a taxonomy for each. Within each taxonomy, levels of expertise are listed in order of increasing complexity. Measurable student outcomes that require the higher levels of expertise will require more sophisticated classroom assessment techniques.

A Psychomotor Domain, Simpson (1972)

Psychomotor includes physical movements, coordination and use of motor skills area (Table 2). Development of these skills requires practice and is measured in terms of speed, precision, distance, procedure or techniques in execution. Psychomotor skills range from manual tasks such as digging a ditch or washing a car, to more complex tasks such as operating a complex piece of machinery or dancing.

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B. Cognitive Domain

Table 8: Cognitive Domain and its Level of Expertise

S/N	Category	Examples	Keywords	Technologies
1	Remembering Recall or retrieve previous learned information	-Recite a policy -Quote prices from memory -recite safety rules	Defines, describe, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states	Bookmaking, flash-cards, rote learning based on repetition, reading
2	Understanding Comprehending the meaning, translating, interpolation and interpretation of instructions and problems. state a problem in one's own word	-Rewrite the principles of test writing. -Explain in one's own word the steps for performing a complex task. -translate an equation into a computer spreadsheet	Comprehends, convert, defends, distinguishes, estimates, explains, extends, generalizes, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates	Create an analogy, participating in cooperative learning, taking notes, storytelling, internet search
3	Applying Use a concept in a new situation or unprompted use of an abstraction Applies what was learned in classroom into novel situation in the work place	-use a manual to calculate an employee's vacation time -apply laws of statistics to evaluate the reliability of a written test	Applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves and uses	Collaborative learning, create a process, blog or practice
4	Analyzing Separates material or concepts into components parts so that its organizational structure may be understood Distinguishes between facts and inferences	-troubleshoot a piece of equipment by using logical deduction -recognize logical fallacies in reasoning -gathers information for a department and selects the required task for training	Analyzes, break down, compares, constructs, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates	Fishbowls, debating, questioning what happened, run a test
5	Evaluating Make judgment about the values of ideas or materials	-select the most effective solution -hire the most qualified	Appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes,	Survey, blogging

		candidates -explain and justifies a new budget	discriminates, evaluates, explains, interprets, justifies, relates, summarizes. supports	
6	Creating Builds a structure or pattern from diverse element. Put part together to form a whole with emphasis on creating a new meaning or structure	-write a company operation or process manual. -design a machine to perform a specific task -integrate training from several sources to solve a problem -revises and process to improve the outcome	Categorizes, combines, compiles, composes, creates, devices, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes	Create a new model, write an essay, network with others.

Table 9: Psychomotor Domain and its Levels of Expertise

S/N	Category	Examples	keywords
1	Perception (awareness) Ability to use sensory cues to guide motor activity These ranges from sensory stimulation, through cue selection to translation	-detects non-verbal communication cues -estimation where a ball will land after it is thrown and then moving to the correct location to catch the ball -adjusts heat of stove to correct temperature by smell and taste of food -adjusts the height of forks on a forklift by comparing where the forks are in relation to the fork pallet	Chooses, describes, detects, differentiates, distinguishes, identifies, isolates, relates, selects
2	Set Readiness to act. It includes mental, physical and emotional set These three sets are dispositions that predetermine a person's response to learning	-knows and acts upon a sequence of steps in a manufacturing process -recognizes one's ability and limitation -shows desire to learn a process (motivation) -related to "Responding to phenomena" -affective domain	Begins, displays, explains, moves, proceeds, reacts, shows, states, volunteers
3	Guided Response The early stages in learning a complex skill that includes limitation and trial and error Adequacy of performance is achieved by practicing	-perform a mathematical calculation as demonstrated -follows instruction to build a model -respond to hand signals of instructor while learning to operate a fork lift	Copies, traces, follows, reacts, reproduces, responds
4	Mechanism (basic proficiency) This is the intermediate stage in learning a complex skill Learned responses have become habitual and the movement can be performed with some confidence and proficiency	-use a personal computer -repair a leaking faucet -drive a car	Assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches
5	Complex Overt response (expert) The skillful performance of motor acts that involves complex movement patterns Proficiency is indicated by a quick accurate and highly coordinated performance requiring a minimum of	-maneuvers a car into a tight parallel parking spot -operate a computer quickly and accurately -displays competences while playing the piano	Assembles, builds, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches Notes: The keywords are the same with mechanism, but we have

	energy This category includes performing without hesitation and automatic performance For example, players often utter sounds of satisfaction or expletives as soon as they hit a tennis ball or throw a football because they can tell by the feel of the act what the result is		adverbs or adjectives that indicates that the performance is quicker, better, more accurate
6	Adaptation Skills are well developed and the individuals can modify movement patterns to fit special requirements	-respond effectively to unexpected experiences -modifies instructions to meet the needs of the learners -performs a task with a machine that it was originally intended to do (machine is not damaged and there is no danger in performing the new task)	Adapts, alters, changes, rearranges, reorganizes, revises, varies
7	Origination Creating new movement pattern to fit a particular situation or specific problem Learning outcome emphasizes creativity based upon highly developed skills	-construct a new theory -develops a new and comprehensive training programming -creates a new gymnastic routine	Arranges, builds, combines, composes, constructs, designs, creates, initiates, makes, originates

C. Affective Domain, Bloom et al(1956)

The affective domain (Table 3), Krathwohl, Bloom, Masia (1973) includes the manner on which we deal with things emotionally such as feelings, values, appreciation, enthusiasm, motivations, attitude.

Table 10: Affective Domain and its Levels of Expertise

S /N	Category	Examples	Keywords
1	Receiving Phenomena Awareness, willingness to hear Selected attention	-Listens to others with respect -listen for and remember the name of newly introduced people	Acknowledges, asks, attentive, courteous, dutiful, follows, gives, listens, understands
2	Responds to Phenomena Active participation on the part of the learner Attends and reacts to a particular phenomena Learning outcomes may emphasize compliance in responding, willingness to respond or satisfaction in	-participates in class discussion -gives a presentation -questions new ideals, concepts, models etc in order to fully understand them -know the safety rules and practice them	Answer, assists, aids, complies, conforms, discusses, greets, helps, labels, performs, presents, tells

	responding (motivation)		
3	Valuing The value or worth a person attaches to a particular object phenomenon or behavior Valuing is based on the internalization of a set of specified values while clues to these values are expressed in the learner's overt behavior and are often identifiable	-demonstrates belief in the democratic process -is sensitive towards individual and cultural differences (value diversity) -shows the ability to solve problems -proposes a plan to social improvement and follows through with commitment -informs management on matters that one feels strongly about	Appreciates, cherishes, treasures, demonstrates, initiates, invites, joins, justifies, proposes, respects, shares
4	Organization Organizes values into priorities by contrasting different values, resolving conflicts between them and creating a unique value system The emphasis is on comparing relations and synthesizing values	-recognizes the need for balance between freedom and responsible behavior -explains the role of systematic planning in solving problems -accepts professional standards -creates a life plan in harmony with abilities, interests and belief -prioritizes time effectively to meet the needs of the organization, family and self	Compares, relates, synthesizes
5	Internalizes Values Has a value systems that controls their behavior The behavior is pervasive, consistent, predictable and most important characteristics of the learner Instructional objectives are concerned with the students general patterns of adjustment (personal, social, emotional)	-shows self-reliance when working independently -cooperates in group activities (displays team work) -uses an objective approach in problem solving -displays a professional commitment to ethical practice on a daily basis -revises judgment and changes behavior in light of new evidences -values people for what they are not, how they look	Acts, discriminates, displays, influences, modifies, performs, qualifies, questions, revises, serves, solves, verifies.

Elvira Popescu, (2012) in his research paper, "Providing Collaborative Learning Support with Social Media in an Integrated Environment" advocated the use of an integrated social learning environment which aggregates several web 2.0 tools (Wiki, blog, microblogging tool, social bookmarking tool, media sharing tools). The platform (tool) developed was called eMUSE (empowering MashUps for Social E-learning). A Mashups represent a combination of data and/or functionalities from one or more external source to create a new web application. eMUSE (Java-based, MYSQL as back-end with XML technologies and JS charts library) provides value added services for both students and teachers which comprises of Learner tracking functionality, Monitoring and visualization features and Grading and evaluation support.

He further reiterated that, "with web 2.0, the user is not just a content consumer but also content generator (often in collaborative manner)" which is in line with Hain, S.; Back, A's contribution-based pedagogies which states that collaboratively creating learning resources and sharing them with others are promising practices through which students can learn efficiently.

He integrated Web 2.0 tools into his platform by means of MashUps offering the following functionalities:

Integrated access to all the Web 2.0 tools selected by the instructor for the course at hand: common access point, detailed usage instructions, summary of the latest activity. Retrieval of students' actions with each tool and store them in a local database. Summary of each student's activity, including graphical visualization, evolution overtimes comparisons with peers, as well as aggregated data. Computer a score based on the recorded students activity (following instructor-defined criteria) and Provide basic administrative services (authentication service, enroll students to the course, edit profile etc.)

eMUSE include a variety of tools that can be integrated in their course: Blogger, MediaWiki, Twitter, Delicious, YouTube, Picasa, Slideshare. In eMUSE, the access to the tools was mostly made by means of open APIs (in case of YouTube, Slideshare, Picasa and Twitter) and also directly through feeds when this was more convenient (in case of Blogger & Delicious) or even by direct access to the Database (in case of the locally installed MediaWiki). The list of actions include various types of learning activities: Creating content, Social interactions, Organizing content, Communication and feedback.

Students' eMUSE main functionalities include an integrated learning space, with a common access point to all the web 2.0 tools selected by the instructor, including updates of the latest activity; a summary of each student's involvement, including pie/bar/line charts, evolution over time, comparisons with peers, as well as aggregated data and a preliminary score computer based on the recorded students activity, following instructor-defined criteria.

Instructors' eMUSE (control panel) with the main functionalities include configurable course by setting up the associated social learning scenario and selecting the web 2.0 tools to be used; student management (course enrolment, centralized access to students' accounts on each web 2.0 tool, grading information); and collect data on students' activity, search and browse students' actions, visualize course statistics, detailed charts of student involvement and comparative evaluation.

eMUSE student home page:

- includes an overview of latest peer activity from the top menu, one can see:
- the list of peers and their corresponding tool accounts
- the list of available tools, including detailed usage instructions
- the list of her actions, filtered by several criteria
- graphical visualizations of her activity……
- configure grading scheme: define grading categories (i.e. individual contributions, peer feedback, communication skills etc.)
- assign different weights to each action type inside each category, based on the particularities of the course

  the overall score will be a weighted sum of all defined categories

Marjan Laal *et al*, (2011) in a paper, "Benefits of Collaborative Learning" stated that: Collaborative learning (CL) is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product. There are a number of benefits that are associated with the concept of collaborative learning (CL). It is through understanding the benefits, that we can truly use this learning style to our benefit. Before one can make a judgment on the merits of CL, it is important to understand exactly what CL is, (Marjan Laal et al, 2011) cited (Annett, N., 1997).

The underlying premise of collaborative learning (CL) is based upon consensus building through cooperation by group members, in contrast to competition in which individuals best other group members. CL practitioners apply this philosophy in the classroom, at committee meetings, with community groups, within their families and generally as a way of living with and dealing with other people, (Panitz, T., 1996).

The term CL refers to an instruction method in which learners at various performance levels work together in small groups toward a common goal. The learners are responsible for one another's learning as well as their own. Thus, the success of one learner helps other students to be successful (Gokhale, A.A., 1995). Marjan Laal et al cited (Woods and Chen, 2010, Johnsons, 1994) that; in order for a CL effort to be more

productive than competitive or individualistic methods, five conditions must be met, as:

- Clearly perceived positive interdependence;
- Considerable promotive interaction;
- Clearly perceived individual accountability and personal responsibility to achieve the group's goals;
- Frequent use of the relevant interpersonal and small-group skills, and;
- Frequent and regular group processing of current functioning to improve the group's future effectiveness.

Marjan Laal et al, (2011) concluded that, CL compared with competitive and individualistic efforts, has numerous benefits and typically results in higher achievement and greater productivity, more caring, supportive, and committed relationships; and greater psychological health, social competence, and self-esteem.

Harry Collins, (2010) in his book, "Tacit and Explicit knowledge", identified two types of knowledge, Tacit and Explicit Knowledge. He further sub-classified tacit knowledge as relational, somatic and collective. Harry Collins said, "The relational tacit knowledge captures the idea of whether the pieces of knowledge are tacit or made explicit depends on the relation between the parties" and that "Knowledge cannot be found in the absence of the activities of human". Harry Collins reiterated that tacit knowledge can be splitted into three (3) parts namely strong, medium and weak tacit knowledge. Strong tacit knowledge is one that the individuals can acquire only by being embedded in society so, it is a property of the society rather than an individual. Explicit knowledge has to do with humans communicating via signs, icons, codes or some of such. Moreover, Harry asserted that strings interact with entities and during interactions, it could have physical impact depending on the relationship between them; impress, print or inscribe a similar pattern on an entity; and it can cause an entity to do something that it could not do before called Communicating.

A string is a physical object and it is immediately clear that whatever it is, has effect and what kind of effect this might be is entirely a matter of what happens to it, (Harry Collins, 2010). According to Harry, Communication can be done mechanically or by being interpreted as meaningful by a human. He added that, whether the impact of a string results in a communication also depend on the string and the entity. Harry Collins exposited five enabling conditions of communication. One, gap jumped because all conditions are in place so, a string interacted with an entity and hence communication takes place; secondly, a physical transformation of a string enables it to have causal impact on an entity which is the precondition for communication; thirdly, sometimes, a short string fails to result in a communication but a longer string succeeds in jumping the gap; fourthly, even the transmission of longer string will not result in a communication perhaps because no one or nothing has the wit or will to create the longer string that will do the job or perhaps because no string, however long, will work and finally, longer and carefully structured strings can help minimize the loss caused by translation of strings.

Pieces of icons, signs and symbols from objects such as documents and these objects are used in interactions during collaboration to solve problems. So, objects have impacts on other entities such as actors and activities during collaboration. Strong Tacit knowledge are acquired only by being embedded in a society such as collaborative environment for learning and research.

According to Carlos Coronel, Steven Morris, and Peter Rob, (2010), the basic building blocks of all data models are entities, attributes, relationships and constraints. An object is an abstraction of a real world entity. In general terms, an object may be considered equivalent to an Entity Relation (ER)'s model. An attribute describes the properties of an object such as name, social security number, and date of birth for an object - PERSON. A relationship describes an association among objects. Relationships are bidirectional. A constraint is a restriction placed on the data and constraints are important because they help to ensure data integrity. Constraint are normally expressed in the form of rules such as employee's salary must have values that are between 6,000 and 350,000. Properly written business rules are used to define entities, attributes, relationships and constraint. Tables are related to each other through the sharing of a common attribute (value in a column). Objects that share similar characteristics are grouped in classes.

Database designs starts with an abstract view of the overall data environment and add details as the design comes closer to implementation. There are three level of abstractions: external, conceptual and internal.

Entity Relation Diagram (ERD) is used to represent the external view. A specific representation of an external view is known as an external schema. Each external schema includes the appropriate entities, relationships, processes and constraints imposed by the business unit.

A conceptual model is used, graphically represented by an ERD to integrate all external views with a single view known as conceptual schema. Generally, the term Logical Design is used to refer to the task of creating a conceptual data model that could be implemented in any DBMS.

The Internal Model maps the conceptual model to the DBMS. This means that the designer should match the conceptual model's characteristics and constraints to those of the selected implementation model. An Internal schema depicts a specific representation of an internal model, that uses the database constructs supported by the chosen database. The Relational database model has three well defined components: a logical data structure represented by relations; a set of integrity rules to enforce that the data are and remain consistent over time and a set of operations that defines how data are manipulated. These principles guide the principles of modelling an object in the databases.

Okunoye Olusoji, Fausat Oladejo and Victor Odumuyiwa, (2010), in a paper, "Dynamic Capitalization Through Annotation among Economic Intelligence Actors in a Collaborative Environment" cited Odumuyiwa V. & David A., (2010) as having defined Economic Intelligence (EI) process as information collection, processing and distribution with the goal of reducing uncertainty in decision making. They added that, knowledge produced in the course of collaboration among actors need to be capitalized for reuse in future and that the questions they intended to answer were: how will annotation be represented, exploited and reused in EI context?; what is the appropriate knowledge capitalization model and how will interactions be managed among collaborating EI actors?. Moreover, "We refer to the knowledge on actors, their tasks and the results of their activities in resolution of decision problem as knowledge Resources (KR)", they asserted. Okunoye O. et al defined Dynamic Capitalization as an approach in which acquisition of knowledge resources covers the communication among actors in the course of resolving a decision problem as well as the process of validation of knowledge resources for reaching concession among actors is also captured with annotation process. They proposed "Enabling Group Awareness" as an approach to managing interactions among Economic Intelligence actors. They explained further that, when two or more work together on a problem; each generates a multitude of signals from each other in a group which provides an understanding of the actions and intentions of the group. Okunoye O. *et al*, (2010) quoted Lonchamp J., (2007) while defining awareness as the term used to denote the knowledge that results from the perception of signals emitted by group members. They spelt out their approach of managing interactions among actors by implementing three levels of group awareness vis-à-vis Workspace awareness which allows EI actors to have knowledge about the state of the shared workspace and its evolution; Presence awareness which allows the knowledge of actors that are online at any given time and their availability and lastly, Activity awareness which handles the communication of all activities being carried out by the different actors in the collaborative environment. "It allows the actors to be aware of one another's activities in real-time. During the Economic Intelligence processes, objects are produced and collections of objects forms knowledge.

Xuemao Wang et al, (2005) published, "Managing and Sharing Knowledge through Portal: The John Hopkins University Libraries' Experience". According to Xuemao Wang et al., knowledge is a fact or a condition of knowing something with familiarity gained through experience or association or acquaintance with or understanding of a science, arts or technique. Knowledge management is "the process by which an enterprise consciously and comprehensively gathers, organizes, shares and analyses its knowledge to further its aims". From the conceptual value perspectives, "KM is the act of creating value from the intangible assets of an organization". By the practical process definition, KM consists in the identification, optimization and dynamic management of the intellectual assets possessed in explicit form by persons or communities". According to Xuemao Wang et al , "a Portal is a website that aims to be an entry point to the world wide web, typically offering a search engine and/or links to useful pages and possibly news or other services …". "Enterprise Information Portal are applications that enable companies to unlock internally and externally stored information and provide users with a single gateway to personalized information needed to make informed business decisions", Xuemao Wang et al. Portals were categorized into two, namely: Horizontal Portals e.g. MyYahoo and MyMSN and Vertical Portals which concentrates on one particular subject e.g. technology or library services. This review concerns this research paper in that pieces of objects form knowledge and knowledge gathered on collaborative platform can be persisted for future use.

According to Colle and Roman, (2002) in a research report titled Collecting and Propagating Local Development Content, considered Local Content to "broadly mean the processing and diffusion of information customized in any suitable format to fit the needs of a specific community." In this study, we propose that local content is the expression of the locally owned and adapted knowledge of a community – where the community is defined by its location, culture, language, or area of interest. This means that local content is not something that is broadcast to or necessarily used by members of a defined community, although this is not excluded. It includes any external or global content that has been transformed, adapted and assimilated into the knowledge base of the community. Local content is exchanged and shared, locally or globally, in various formats, packages and media. When it is disseminated and is accessible that uses digital means, it can be termed 'eContent'. Easier access to globalized knowledge is fast turning us into 'consumers' of distant and potentially irrelevant information. In a search for ways to promote local content, we have few guidelines to follow. Invest resources in a wide spectrum of local initiatives that create or communicate genuine local content; work with existing eContent, networking producers and intermediaries to exchange and deliver development-oriented content and examine ways to provide incentive financing for local content. The fact that objects produced in a collaborative environment is first local or internal and when capitalized into knowledge, it could be global for other people's use make this review relevant to this paper.

Gerry Stahl, Timothy Koscmarn & Dan Suthers, (2006) in their research paper, "Computer-Supported Collaborative Learning: An historical perspective", Computer Supported Collaborative Learning (CSCL) is an emerging branch of the learning science concerned with studying how people can learn together with the help of computers. CSCL is based on precisely the opposite vision: it proposed the development of new software and applications that brings learners together and that can offer creative activities of intellectual exploration and social interaction.

Gerry Stahl et al, differentiated E-learning from CSCL that:

- CSCL is more than posting of content but motivation and interactions that motivates learning better
- It increases the teacher effort per student: teacher must lead, motivate or guide each student, through on-going interaction and a sense of social presence
- CSCL stresses collaboration among students with computer support not just reacting in isolation to posted materials. Requires skillful planning, coordination and implementation of curriculum, pedagogy and technology
- CSCL is concerned with a form of distant of face-to-face interaction either synchronously or asynchronously.

They referred to Dillenbourg, P. & Traum, D., (1999) while distinguishing between cooperative learning and collaborative learning: In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work 'together'. They also referred to Roschelle, J. and Teasley, S., (1995) definition of collaboration that "collaboration is a process by which individuals negotiate and share meanings relevant to the problem – solving task at hand. Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem.

The goal for design in CSCL is to create artifacts, activities and environments that enhance the practices of group meaning making. To create the possibility of an enhanced form of practice require more multifaceted forms of design (bringing in expertise, theories and practices from various disciplines): Design that addresses curriculum (pedagogical and didactic design), Resources (information sciences, communication sciences), Participation structures (interaction design), Tools (design studies) and Surrounding space (architecture), Gerry Stahl et al reiterated.

They referenced (Schrage, 1995) as having defined Collaboration as the "process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding". The distributed and shared expertise approaches emphasize that shared space is a fundamental requirement for the creation of shared understanding. The space then becomes a frame of reference for the collaboration and provides an environments in which collaboration can occur. Objects are produced, used and reused in collaboration to produce other objects in collaborative environment so, discussing collaboration as a concept is relevant.

III COLLABORATIVE SPACE, SUBSPACES AND INTERACTIONS IN AN ICT-BASED ENVIRONMENT

In this research work, we propose a collaborative environment as a conceptual collaborative space which contains a set of other sub-spaces which individually represents an entity in the space.

In our research work, we identified two major division of subspaces, Active and Passive subspaces. For example, the active subspaces are the human entities in a collaborative space while the passive subspaces are activities and objects generated during interactions in a collaborative space. The active subspaces are subdivided into positive and negative subspaces. We propose that the positive subspaces be the experienced actors whereas the negative subspaces are the mentee in a collaborative space.

These categories could co-exist as subspaces of the same or disparate ranks. For example, they could co-exist among experienced collaborators such as lecturers, full-time researchers, supervisors, researchers or among Ph.D students and young scientist peers or even across the two ranks. This is evident as experienced collaborators could not be of the same experience, cognition and skills level. In a collaborative space, there exist interactions among the subspaces. These interactions promote learning in either teaching or research. Impactful interactions that result in learning and decision making in research are more between two or more positive and negative subspaces than between two or more negative subspaces or between two or more positive subspaces. That is, learning is more, either in teaching or research, when collaborators are of disparate experience and skills.

We identified that, the interactions between the positive and negative subspaces are usually conflictual because of the knowledge and skills differential. Interactions can take place in the collaborative space either, vertically or horizontally. We propose that the vertical interaction is that between/ among two or more positive and negative subspaces whereas, it is horizontal when interactions are among negative subspaces mainly or positive subspaces alone.

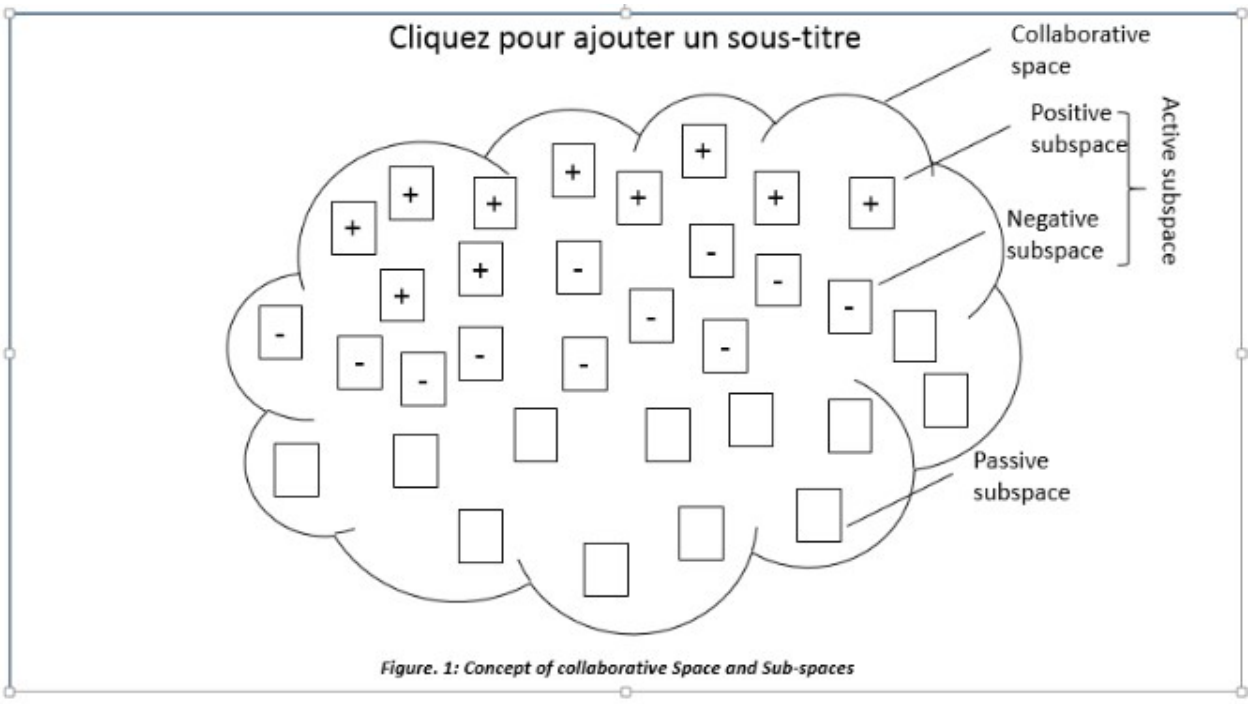

Figure. 1: Concept of collaborative Space and Sub-spaces

Figure 1:

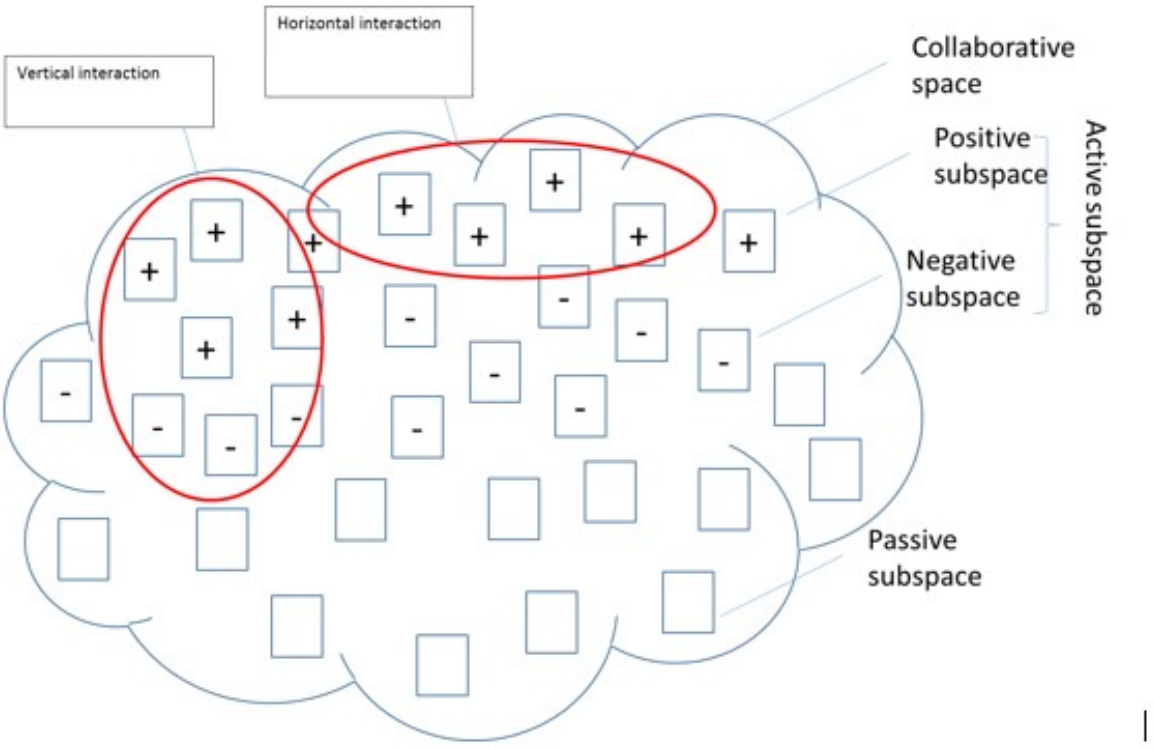

Figure 2: Interaction among the positive and negative sub-spaces in a collaborative space

Interaction also takes place among the passive subspace too but it is non-directional because they are non-living entities. We propose that each active subspace has a unique identity and that the identity is made of two sections namely, innate identity and acquired identity. The identity is innate when it is personal such as height, sex, age while acquired identity has to do with qualities that are developed such as qualification, designation, contributive activities and roles. The collaborative space is unique and for a specific purposeful domain at a time. For example a collaborative space could be designed for educational purposes or marketing but not the two at the same time.

A Interaction Forms in the Collaborative Space

In this research work, we found out that the interactions that take place among the subspaces are homogeneous and heterogeneous. One, Homogeneous Interaction. When two or more actors in the same domain are collaborating, contributions from each of them such as illustrations, diagrams, algorithms and frameworks are recorded and specified in term of documents. The actors speak same professional terms, their objects content are contributed from the same domain.

Secondly, Heterogeneous Interaction. Two or more researchers are conducting research to solve a decisional problem but from different domain (multidisciplinary). A statistician contribute statistically, an historian contribute historically, a medical personnel and a computer professional contribute their quota forming objects whose origin are from different domains yet for the solution of same problem. But then the role a subspace attains at a time can influence the nature of interaction in a collaborative space. For example, if an active subspace say an actor, manages an activity, the interaction between the managing actor and the other subspaces is one-to-many. We discovered that he interacts with the collaborative space on one hand, setting tools to be used in the collaborative environment, schedules announcements, reminders, co-ordinates the event's successful kick-off. Secondly, this subspace also interacts with other active subspaces posing questions or a decisional problem on the collaborative space on the resolution of a problem. We propose a third interaction between the managing actor and the passive subspaces such as activities and objects generated during the course of learning and research situation.

B Dependency among the Subspaces in the Collaborative Space

We identified in this work that the active subspace (positive or negative) depend on the passive to function in a collaborative space. We propose a functional dependency between the active and passive subspaces. A functional dependency defines the attachment an entity has to another before it could act, react or perform. The active subspace needs, for example, activities to manipulate collaborative learning and research objects. In activities, learning and research objects such as theories, specific objectives, hypothesis, documents, annotations, and bookmarks are employed. The activities or events acts as vehicles for learning or research objects. A kind of progressive evolution is proposed, in this research, for either the active or passive subspaces in the collaborative space. A negative active subspace for example a mentee may evolve to become a positive subspace in time depending on change in qualifications, designations and experience overtime. For example, a young scientist or Ph.D student can eventually rise, due to change in qualifications and experience to the position of a researcher, lecturer, fulltime researcher or even another student's supervisor. In this collaborative space the history of such an evolution must be tracked and kept overtime. A passive subspace can also evolve to have an evolutional history with time. For example, an initial document can continually be annotated overtime as needed and each time it is modified, it is saved as another version incrementally.

Among the passive subspaces, for example, activity and objects, there exists another kind of bidirectional and mutual relationship. For example, in activities, objects are generated while these objects in turn, facilitates activities. That is, in activities, subspaces interact and in interactions, objects are produced. We have deduced based on figure 3 below that in the web of interaction-filled activity, objects are generated.

IV OBJECTS REPRESENTATION

The objects used in the collaborative learning and research environment are annotations, usage documents, thesis, write-ups, podcasts and discussion traces. These objects collectively have general attributes common to all such as object identification (obj_id), object description (obj_desc), object rating (obj_rating), object format (obj_format) and object creation date (obj_date). There are other attributes such as object author (obj_author), object administrator (obj_admin), object supervisor (obj_supervisor), object coordinator (obj_coord) and object version (obj_version). To avoid redundancy in the databases, obj_author, obj_admin, obj_supervisor, obj_coord are all grouped as ACTOR. A single object could be used in many ACTIVIT-ies. Object activities (obj_activity) will be a list as an attribute and so, ACTIVITY is an entity on its own. Obj_version is an attribute of the OBJECT entity that evolves with time. So, obj_version becomes another entity as VERSION such that evolution could be tracked with timestamps.

This research work proposed that an OBJECT be represented or identified with the following attributes:

obj_id= unique identifier differentiating one object from another

obj_creator = actor who created an object

obj_desc= this attribute gives object title, purpose or description

obj_rating = it is the document content value attribute

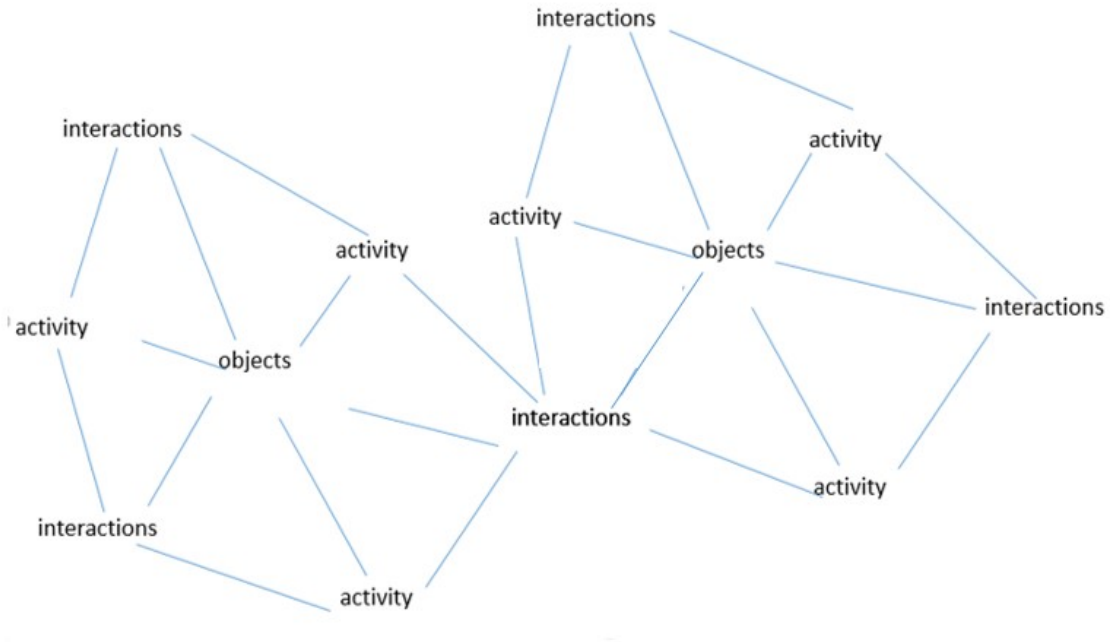

Figure 3: Relationships among the Passive Sub-spaces

obj_format = is the attribute for the file type

obj_date = object creation date attribute

obj_version = version attribute

obj_usage = activities in which an object has been used.

So, we propose a model for representing an object:

Objmodel =(obj_id, obj_desc, obj_format, obj_date, obj_rating, {obj_usage}, {obj_creator}, {obj_version})

Where,

Objmodel = model for an OBJECT

{Obj_creator} = object creator or users may be more than one hence, it is a set of elements.

obj_id= object identification

obj_desc= object description

obj_date = object date of creation

obj_format= object format

obj_rating = the quality or value of an object

(obj_usage} = what an object has since being used for, It is also a set or list of items

{obj_version} = object version which may be a set of versions tracked with timestamps

The above representation could enhance learning and research. For example, a scenario where a Ph.D student needs a document on research methodology. He searches the learning and research platform and arrive at some results. The resulting objects are not of the same value or rating in content. An object authored by an experienced Professor could be of greater value than one by a Ph.D student colleague or vice-versa. Object rating attribute will aid users of objects to discern the reliability of a particular documents, even when the user eventually decided to still use such for whatever purpose. Likewise, object format will specify the file type, object version attribute will hint the users of the versions availability information of the object, object date attribute helps to identify how recent the object was created or used, object usage spells out what an object has been used for and object description will provide the keywords for searching. The object can then be searched either by object description or object constituent phrases. The evolution history of usage, version and annotation will be easy to track too that uses this representation.

The objects versioning can be achieved when an actor who can create, use or administer an object say an annotation, logs onto a system, his details are tracked. Document he annotated is identified, annotation added is noted, annotated document version, annotated document format, annotated document description and annotation date serves as the properties of the document's new version while the annotation content is the body of the document, all saved in a new version and in a particular file format to facilitate reuse.

Knowledge unspoken or unexpressed is invariably latent knowledge. Knowledge are expressed in objects. Knowledge must be specified in terms of documents to be useful for future reference and use. Knowledge possessed by an ACTOR is subject to decay, hoarding

and outright extermination if not rendered in form of documents. Unexpressed or unspoken knowledge has to be recorded such that it could be replayed or used over and over so that knowledge gained can be further used to construct new knowledge for future resolution of problems. For example, if a research brainstorming session between a supervisor and his Ph.D student on a given research process is not recorded probably in video, audio or text, the student might be able to use the knowledge gained for a while but they are likely to forget due to disuse and knowledge decay much more later. If rendered in form of documents, it could be used or replayed over and over or even be passed to some other students after many years.

V. Derived Properties of Objects in a Collaborative Space

Sequel to our discussion in this study, we propose some four properties for an object. Object content could be obsolete but not totally lost or useless. The knowledge in such obsolete learning and research objects are fundamental principles and scaffold for new knowledge. First, objects are evolutionary. One discovery serves as a take-off space for another new discovery. Objects transcend generations and not stationary. It could grow over years into another new object entirely but retain some initial innate properties. For example, some learning objects were earlier recorded on record plates, later came cassette tapes many years ago. The cassette technology evolve into VHS tapes and later compact discs technology and later into flash or jump drive and finally into micro SD technology yet, it retains the attribute of recording and play-back. With technology, objects also evolve from one format into another. For example, VHS tape video content are, these days converted into mp3 or mp4 format and re-written on compact disc. The new resulting object could be better in rendering and production than the previous.

Secondly, object has a dependency property on ACTIVITY entity. ACTVITY entity has the following attribute: activity identification (ACT_ID), activity description (ACT_DESC), activity location (ACT_LOCATION), activity date (ACT_DATE), activity start time (ACT_ST_TIME), activity end time (ACT_END_TIME), activity object (ACT_OBJECT) but because the OBJECT employed in collaborative activity could be a list, it has to become an entity on its own as OBJECT. ACTOR uses OBJECT, during interaction, to participate in ACTIVITY. The dependency of OBJECT on ACTIVITY could be explained in WHAT, WHO, WHEN, HOW, and WHY perspectives.

WHAT: WHAT objects are used in which ACTIVITY

WHO: WHO used certain OBJECTs to participate in which ACTIVITY

WHEN: At what time and date is an OBJECT used in an ACTIVITY

HOW: HOW was an OBJECT used in an ACTIVITY

WHY: WHY was an OBJECT used in a particular ACTIVITY

In an ACTIVITY, objects interact.

The third property of an object is complexity property. For example, a researcher is conducting a research in a particular domain, the researcher searches for related works as foundation for his arguments or innovative discussion, he references other researchers knowledge, compare and contrast two or more techniques, algorithm and combine their strength to improve on existing versions. While doing this, there are cross reactions of many other researchers' ideas into his own new idea, discussion and results. When a researcher or Ph.D. student has eventually ended up with a new idea which has its foundational theory, ideas, techniques and algorithm on other researchers' work, the new idea or result is usually complex. The new idea might not be separable into its contributive components from constituent sources, they are fused so, objects have complexity property.

VI Forms of Objects in a Collaborative Space

We identified the following forms of objects in a collaborative space vis-à-vis Initial Object, Documented objects, Annotative objects and Pointer objects. Initial object is the first version of an artifact produced during a collaborative session for example, a saved chat session between two or more actors. This can form the basis of another day's deliberation on a solution to a decisional problem. An annotative objects are documents on which comments and bookmarks have been added and saved in versions. For example, an Initial object is edited and additional content is appended, it becomes an annotated object. The original of such objects are preserved as version-1 while subsequent edited copies follow in incremental version order. Documented objects are artifacts such as papers, publications, periodicals, white papers that are being used in the process of collaboration while Pointer objects are objects that actors found useful on the learning or research platform and so point it out to some other actors such it could be of use at one time or the other.

VII Conclusion

Objects in a collaborative environment are entities created, used, versioned during interactions and activities. Adequate representations of objects aid actors' effective use for research purposes in collaboration. They cannot exist without human activities. Objects derived properties (evolutionary, activity dependency and complexity properties) assist actors with information which version to prefer, in which kind of scenario an object had been previously used in relevance to his current needs and nature of objects. Objects must be well represented in a collaborative environment for ease of retrieval and reuse.

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