PBL and Concept Acquisition

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Abstract

The objective of this presentation is to study to what extend a PBL learning process helps in concept acquisition within the framework of an approach based on the principles of Cognitive Psychology, Constructivism, and high-level mental skills. The main research questions of this paper are the following: To what extent a PBL based strategy will help knowledge building? What are the pre and co requisites for a successful PBL learning process from a cognitive point of view? Is there any relation between the development aspect at the learners' level and the PBL strategy implementation?

Any learning approach may become a mere technical tool if not rooted in a solid ground of a broad methodological vision of education. PBL learning process is not an exception. This is why, and based on the adequate literature, this paper tried to propose specific criteria to be used as reference for any PBL strategy evaluation in terms of quality.

A case study was used to illustrate to what extend the use of these criteria is beneficial, efficient and may help judging the quality of learning strategies.

Keywords: concept acquisition, learning strategy, knowledge building, conceptual fields, quality of learning, PBL.

1. INTRODUCTION

History of Pedagogy is full of innovations and new ideas which resulted in establishing new methods of teaching and learning, of founding schools with new strategies, or in adopting creative methodologies dealing with didactics. At the university level this trend of innovative methods came much later. Laursen and Rasmussen, in their presentation of the Aalborg PBL model, described very well the continuum in higher education stressing the fact that new methodologies do not go against this basic objective. PBL, in the early seventies was one of these changes which emphasizes on the urgency of implementing new didactical approaches in the university educational environment.

At the same time, Cognitive Psychology began in the sixties, with the works of Piaget and his school, introducing a new paradigm in the learning process mainly at the pre-university levels. In the nineties such questioning was raised also in universities. Many questions were raised about the productivity of higher education not only in terms of invested infrastructure but also in terms of pedagogical processes: curriculum building, concept acquisition, and mastery of high-level mental skills. Very similar questions were asked in PBL strategies and in cognitive based approaches.

To what extent is it important to base a PBL strategy on this theoretical background in order to ensure the continuity of the process, its quality and its effectiveness? Such questions are becoming more urgent with the emerging new learning methods and techniques [1], some of them inspired by the PBL approach [3]. After presenting the theoretical background, this article will try to link these two trends and to propose, based on a case study, criteria for ensuring the quality of a PBL strategy.

2. CONCEPTUAL FIELDS THEORY

The cognitive approach described here is based mainly on the original works of Gérard Vergnaud [12] in knowledge construction. The main innovation of Vergnaud was the introduction of the "Conceptual Field" notion, an important starting point when it comes to issues of curricular practices.

Definition

According to Vergnaud [11], a concept is defined by the set of situations in which it operates, the set of "invariables" (specific vocabulary or theorems or functions) that make it operational, and the set of symbols that allow communication and expression related to the concept. Mastery of a concept is cumulative and interactive. It needs time to develop, and it needs to be related to other domains of knowledge and to other concepts. This will make the concept an integral part of a more general knowledge entity called a "Conceptual Field", and there is no way to separate specific concept acquisition from conceptual field building.

While acquisition of knowledge progresses, some conceptual fields will "intersect" (e.g., the conceptual field of "vectors" in mathematics and the conceptual field of "forces" in physics), some will be totally "closed" at a certain time (the conceptual field of "additive structures" at the sixth grade) whereas others will "begin" much later (the conceptual field of "integration" at the freshman level). The process of envisioning any curriculum content in terms of conceptual fields is far from being exhausted theoretically. However, as a practical matter, we need to know to what extent a conceptual field may be developed in a specific moment of knowledge construction, and in relation with which other conceptual fields. Such an approach must call into question not only the "independence" of the different concepts involved in building the learner's knowledge, but also the foundations of didactic techniques and of curriculum design. The theoretical importance of such a background for curriculum design in Higher Education was developped by Nahas in [5].

Relation with Didactics

To mention an example, the teaching methods currently in use in HE ask physicists and engineers to learn mathematical information in an artificial classroom environment and to apply it later to real world problems. In such cases, it is often difficult to relate such classroom situated theoretical conceptualizations to real life applications, making problem solving difficult, perhaps impossible. In traditional lecture based teaching approaches the student is often left alone to find the path from theory to application, according to the following model.

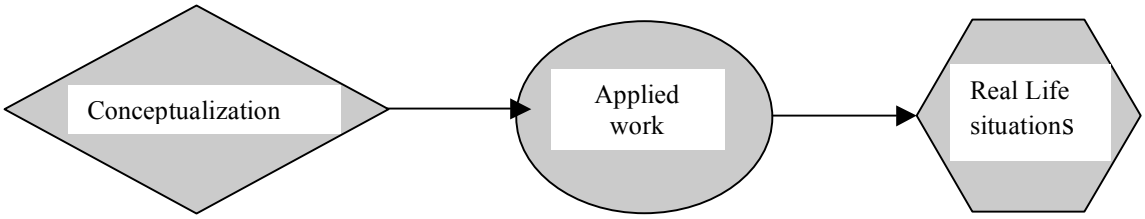

Figure 1.

The cognitive approach provides for a *contextualization* of the curriculum content by adopting an *experimental* basis for knowledge acquisition. Conceptual field theory considers the important role of the preparatory phase in *knowledge building* is to help the learner master different cognitive schemes that lead to the ability to put concepts and theorems into action. This is why the preparatory phase has to be based on developing the aptitudes of the learner to discover by them prior to theoretical conceptualization.

In general, this cognitive methodology leads to a *process of learning* which stresses critical thinking and incorporates the successive steps needed to transform information into knowledge. In such a process, productivity is not measured in terms of time, but in terms of ability to respond to the market, which often complains that the newly hired graduates need intensive training to become productive. The cognitive approach suggests that all didactic, lecture-oriented teaching techniques be adapted to comply with the imperatives of constructivism.

The difference between the traditional approach and the cognitive one is a difference in depth between acquisitions of information that is applied later on to real life situations, and knowledge building anchored from the very beginning in real life situations. In effect, real life applications are used to motivate theoretical understanding and enhance future application in an inductive manner. Figure 2 gives an idea of the typical model according to this approach.

3. CONCEPTUALIZATION PROCESS AND PBL

« Conceptualization » is the dynamic process of knowledge acquisition which is by itself a complex system. This is a system where information, skills, competencies, high mental skills, language mastery, and different techniques are involved within a pedagogical environment which, in turn, depends on the learner, the social situation, and the learning tutorship. The value of any teaching /learning method will depend on the support it guarantees for an efficient development of the different components of this process. This is why conceptualization goes far beyond the acquisition of one single concept, and is a cognitive continuum.

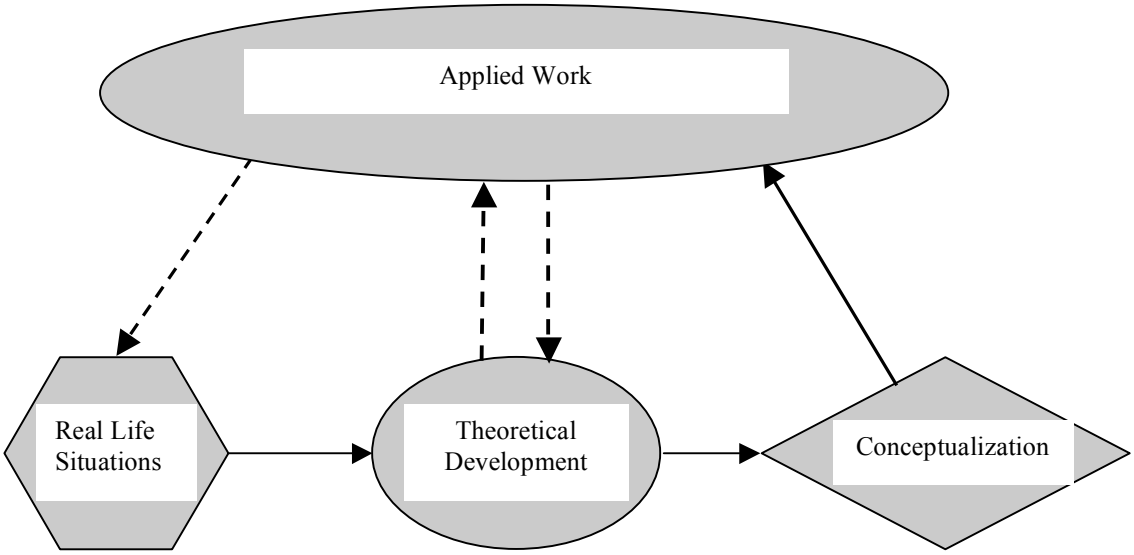

Figure 2.

In-act Acquisitions

One of the key elements of the cognitive process is its respect of the *natural order* of acquisition which takes place always as a result of an *in-act* appropriation of knowledge. This is not only true in the developmental phase but is part of the cumulated information which comes from experience or from experimentation and which is not always formulated clearly. Such in-act acquisition may involve concepts or theorems. This *natural* phase in concept acquisition is somehow neglected in the classical teaching procedures which deny the basic role of *action* in the cognitive process, giving predominance to the informative aspect of teaching instead of its operational component. It is worth mentioning here that the Engeström model of activity [2] does not stress the importance of action in knowledge acquisition while Vygotsky [13] and [14] and Piaget [9] consider it to be a central issue. One may refer to the work of Newman and Holzman on Vygotsky's ideas [6].

Situations and Experimentation

In a research concerned with the conceptualization process, Nahas described what he called the *Communicative Didactical Situation* (CDS) [4]. It purports to be the appropriate encounter where the different components of the process evolve simultaneously. Experience and/or experimentation are at the basis of any in-act acquisition. This can be done in a natural, or didactical, or research environment. In all cases this is supposed to be a kind of CDS. This is where a PBL strategy can be considered to be rooted and can offer to learners the appropriate ground to begin their acquisition process, from a cognitive point of view.

From actions to theory

In the cognitive dynamic process, experimentation is not an aim but is only a phase. Its role is to lead to the knowledge appropriation through the in-act acquisitions. A typical model creates a dialectical relation between

action and theorization, and this is why it can better be associated with a PBL strategy, then the linear model of Tuckman [10]:

Forming ---> Storming ---> Norming ---> Performing

usually considered for communicative learning. But this model does not help, by itself, in creating the dynamic atmosphere conducive to developing a full educational strategy.

The model of figure 2 can be read as in figure 3, to stress this dialectical issue:

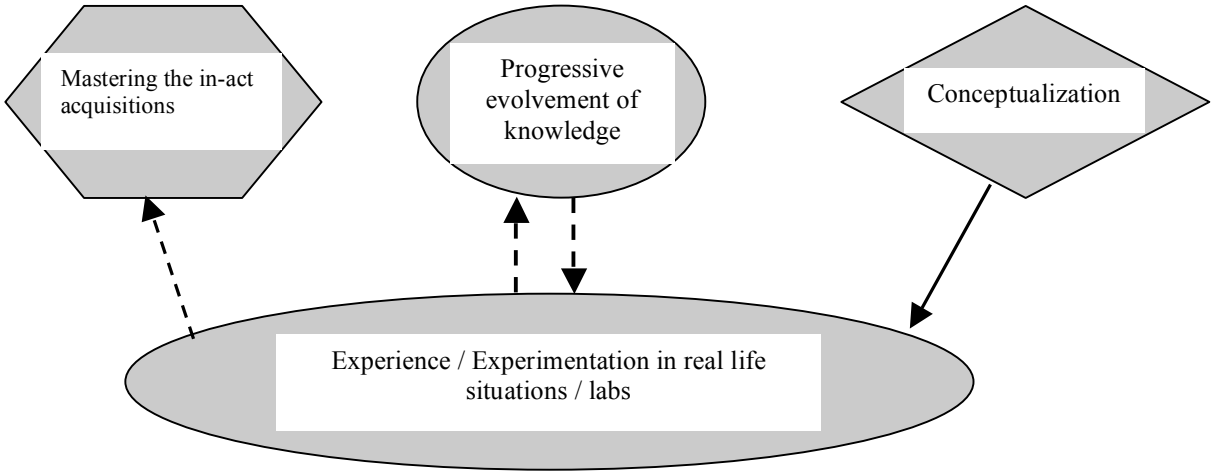

Figure 3.

Knowledge appropriation

Stated in these constructivist and cognitive terms, the problem, still, does not resolve the aspect linked to the human person, which goes beyond contents and techniques. This human aspect has its own constraints, needs and objectives on the personal and community development levels. For the learner, to appropriate knowledge means to master this knowledge and be able to use it creatively. This may be attained only if in the process of learning the learner is the focal point of the process and knowledge appropriation goes beyond accumulation of information.

Tutoring

What is the role of the instructor in this process? Years ago, instructors began to be called "managers of learning". History of Education shows how much the definition of the instructors' roles has changed even though this evolvement has been very slow. With the new technologies, the changes are becoming drastic because the Information Technology is bringing a new source of information very reliable, very wide, and always up to date. But with a learner-centered approach, instructors are called upon to discover themselves as tutors. No magisterial lecturing but guidance through a close collaboration and team work in planning, assessing, and follow up. And because of the human aspect mentioned earlier, this tutorship is responsible of monitoring the development of the high-level mental skills of the learners; mainly critical thinking abilities, experiential capabilities, and modeling competencies.

The PBL model

Going back to the literature on PBL, the common background with the cognitive approach is very clear. A PBL strategy seems to be one of the closest learning strategies to the cognitive process and its theoretical basis as it has been described. But at the same time, a PBL strategy may end by becoming a didactical technique which does not lead necessarily to knowledge building and high-level mental skill acquisition. Two main questions may be asked and need to be answered and monitored: (i) How does a PBL strategy help in developing a curriculum process taking into consideration the cognitive psychology imperatives? (ii) What are the quality

requirements that have to be implemented in order to make sure that the PBL strategy will ensure to the higher education its expected productivity?

4. CURRICULA AND PBL

Utilizing conceptual field theory as a basis for curriculum design has two direct imperatives: (i) the experience of the learner must serve as a cognitive base for knowledge building, and (ii) educational planners must consider the interdisciplinary nature of knowledge. However, these two issues are frequently ignored in the day-to-day life of educational institutions. The PBL strategy may address the two issues simultaneously.

The Curriculum components

Scientists, professors, and researchers in different domains share their expertise and problem solving skills to answer complex scientific questions. Such interdisciplinary approach has proven productive in real world professional settings, but it has not yet become an important component of academic programs neither in universities nor in schools. The cognitive approach claims that, by differentiating between information and knowledge, we may implement a learning strategy, which will avoid this linear assumption. *Information* has to be treated in context, with the proper tools and in an adequate CDS to be transformed into *knowledge*. The cognitive approach stresses the concurrent importance of the two aspects.

Based on this, the content for any academic curriculum can no longer be conceived of as a juxtaposition of courses offered in different service departments with a concentration in the department of specialization. This is why, the academic components of a curriculum can no longer be restricted to: objectives, content and evaluation. The dialectical inter-action between practice and knowledge acquisition has to become an integral part of the strategy. Educators and planners will have to ensure that the applied didactical techniques will give room for the evolvement of the learner's potential and will lead from information to knowledge.

The Developmental Aspect in Knowledge Building

On the other hand, the learner's development is a life time process which begins very early for some basic competencies, such as language mastery and advanced mental skills. While choosing a learning strategy, planners have to bear in mind that some pre-requisites are indispensable for the learners to enable them to cope with the requirements of the strategy. No teaching/learning technique suits all learners. A strategy is not a goal by itself; it will need to be contextualized. The cognitive approach, by stressing the simultaneous evolvement of the different knowledge building components, tries to make sure that the priority is not given to the didactical aspect of the process. Here comes the question about the knowledge building process within the PBL strategy.

Knowledge Building Process and PBL Strategy

Based on the ongoing researches about teaching/learning strategies and the objective analysis of such strategies [8], and considering the schematic model of a PBL strategy in comparison with the process already described from a cognitive point of view, one can say there are five successive levels that need to be thoroughly examined:
A – Establishing the correspondence between the pre-requisites. This aims to make sure that the students have the needed skills to work on a "problem" and that they have the pre-requisite knowledge which enables them to search for new information.
B – Examining the nature of the problem from a procedural point of view. This aims to specify the needed competencies, which will enable the learner to make an adequate information treatment and thus be able to move forward with his inquiries.
C – Examining the adequacy of the problem to content development. This aims to clarify the role of the problem in making the learner move from one level of knowledge to a new one according to the imperatives of the related conceptual fields.
D – Clarifying the steps of the typical solution. This aims to set down the reference for guidance in tutoring the work and leading the learner to the conclusions. This does not mean to have a ready made unique way of problem solving, but to make sure that the knowledge building will reach a result.

E – Establishing assessment criteria. This aims to give the learner a feed back of his achievements not only in terms of information gathering but also in terms of the acquisition of skills, the mastery of competencies and the building of conceptual fields.

Rooting these steps in the cognitive approach will ensure an internal integrity to the strategy, and will lead, to a sustainable continuity in a lifelong process, from early years of schooling. Such guidelines will encourage team work in creating unified guidelines suitable for adoption in different pedagogical situations.

Important Questions

When applying such strategies, educators are often asked about the theoretical background of their approach, but also about more specific issues, mainly:
A – When does such a strategy begin to be applicable?
B – Is such a strategy applicable in isolated cases?
C – Is such a strategy an institutional methodology or is an instructor driven one?

Such questions try to avoid surprises in the pedagogical endeavor, and are rooted in the prevailing atmosphere within the academic body which is resistant to changes. It is important to note that these questions are challenging by themselves for the future planning and implementation of new pedagogical trends on a quality assurance background. Even if answering these questions is a long process and needs dedicated research in different settings, it is important to try to give enough guidelines to launch it.

A case study: launching an answering process

In the following I will relate an experiment which was done in a senior-level class. The course was a course in Education for students not majoring in this field. The experiment was run over three successive years, under similar conditions but using different teaching methodologies.
A - The first year a classical student-centered methodology was used.
B - The second year an *action model* was used based on the Tuckman model [10]: Actions were designed and distributed to student groups. Brain storming on the actions' reports was carried out to launch a conceptualization process.
C - In the third year an Aalborg PBL model was used: The 20 student class was divided in 4 groups. Each group had to work on a specific educational theme. Each team made 3 progress reports to the class during the semester, and presented to the instructor a final report on the project. The projects' fields were totally different with no possible intersection, but the learning outcomes were the same. 50% of the class hours were devoted to lecturing, progress reports presentations, and discussions. The evaluation was based on the progress reports, on two personal works, and on the final report. The following table summarizes the overall results:

Items	*S-C Methodology*	*Action Model*	*PBL Model*
Students Interest	Fair	High	Very High
Acquired new skills	None	Fair	High
Acquired new competencies	Very few	Few	A lot
Students' Involvement in knowledge acquisition	Fair	Good	Very Good
Learning outcomes acquisition	Good	Good	Very Good
Time devoted to reading	Good	Good	Fair
Time devoted to action planning	None	Fair	Very Good
Critical Thinking development	Few	Fair	Good
High Mental Skills involved	Fair	Fair	Good
Scheduled time usage	Sufficient	Sufficient	Insufficient
Content material covered	100%	90%	80%

TABLE 1. Results' Comparison

It is important to note that the students were not aware that such experiments were taking place. The relatively positive results obtained, mainly in the case of a PBL strategy may be considered as an incentive to go further experimenting these strategies in different contexts, linking them to the cognitive approach. In the following I will develop the criteria I used to reach these results.

5. QUALITY AND PBL STRATEGIES

To do so, I propose to adopt the operational definition of the concept as introduced earlier (2.1). I will propose what I consider being the "quality situations", the "quality invariables", and the "quality operators".

Quality Situations

A concept operates only *in situation*. In this context a situation describes the setting of the educational strategy under study. Three situations are proposed.
A - The first situation is related to the knowledge itself. We have to be able to assert if the applied strategy permits knowledge acquisition, emphasizing the fact that knowledge is not an accumulation of information. For example, Internet search engines enable the access to information but are not an adequate situation for knowledge acquisition. The main criterion for a pedagogical strategy resides in offering the possibility to: (i) acquire information, (ii) treat the information, and (iii) build knowledge.
B - The second situation is related to the knowledge appropriation modes. The criteria for this learning situation will have to meet the following conditions: (i) To give room to the acquisition of skills needed by the learner for knowledge appropriation, (ii) To create the learning environment for the mastery of the cognitive procedures as described earlier, and (iii) To offer guidelines for an adequate evaluation of the evolvement of the procedures.
C - The third situation is related to the personal development of the learner. The criteria for this situation will have to respond to the following needs: (i) To ensure the flexibility of the strategy and allow for some *personification* of the learning process, (ii) To create the adequate atmosphere for an efficient tutorship, and (iii) To allow for capacity building in term of team work and communicative capabilities.

Quality invariables

The invariables are the conceptual elements which describe the relations within each situation. The invariables are internal organizational elements for ensuring the inter-dependence of the educational components of the learning strategy.
A – The first type of invariables is related to the *transparency* of the system. It has to show the difference between the theoretical potential of the system and the didactical tools used for a specific content, and in a particular context. For example, *team work* is an invariable of the PBL strategy; it may be used in different ways depending on many factors.
B – The second type of invariables is linked to the transversal components of the process. These invariables have to ensure the adequate liaison between the different pieces of knowledge acquired within the development of a specific conceptual field. Such invariables are for example: networking, performing software, availability of databases, etc.
C – The third type of invariables is related to the longitudinal components of the process. These invariables ensure the possibility of adequate and parallel development of information, competences, and skills for information treatment.

Quality Operators

In order to give the quality concept its operational aspect, we will have to specify the operators needed to assess this quality. Such an assessment has to be reliable and quantifiable as much as possible.
A – The first family of quality operators is related to the *operating modes* of the system as a whole. This has to be done in two different phases: upstream and downstream. In fact any operating mode (a team work process or a field work action, for example) has to be assessed before and after its implementation to be able to give an objective evaluation of its pedagogical value, not only in theory but also within a specific context. Upstream the assessment is mainly a methodological one. While downstream the assessment is mainly operational. Both aspects are equally important for the quality of the strategy.
B – The second family of quality operators is the set of grids which will permit the assessment of the efficiency of a system vis-à-vis all the learning outcomes of a program. Usually an assessment based on such grids is done downstream and its role is not to evaluate a strategy as an absolute, but its efficiency in a specific context. A positive aspect of a grids driven evaluation is the possibility to make a quantification of the results for the scientific future evolvement of the strategy. Such grids will address questions such as: content's percentage covered, work time necessary to cope with the requirements, the material used, the contact hours needed, adequacy and availability of tools, etc.

Cognitive Based Quality Criteria: Example of use

Table1 gives the results of an experiment which was run with three different teaching/learning strategies, over three successive years. The course content, the instructor, the academic year were all the same. The only variables were the strategy and the students. We considered that the classes were quite equivalent in terms of grades and knowledge level, based on their grades and their over-all performance in the institution to which they belong. This is why, our study focused on the strategy itself.

In the first year, even if the methodology was student-centered, it did not take into consideration the imperatives of the cognitive approach. In the second and third years, this approach was taken as the background of the syllabus, but in the second year an *action model* strategy was applied, while in the third year the PBL strategy was applied. In the following, we will analyze the results of Table1, taking into consideration the criteria developed in this paragraph: (5.1) for quality situations, (5.2) for quality invariables, and (5.3) for quality operators.

Criteria	*Classical Methodology*	*Action Model Strategy*	*PBL Strategy*
Quality Situations A	Only the point (i) is satisfied.	Points (i) and (ii) are satisfied.	All the criteria are covered.
Quality Situations B	None of the conditions are met	Point (i) and partially point (iii) are covered.	Points (i), (ii) and partially (iii) are covered.
Quality Situations C	Point (ii) was partially covered.	Points (ii) and (iii) were fairly covered.	All the criteria are covered.
Quality Invariables A	Invariables are quite non-existent.	Teamwork and action planning are the main invariables of the strategy.	Teamwork, planning, field experiment and real life problems are the main invariables of the strategy.
Quality Invariables B	In this strategy, the instructor takes the initiative in asking for such invariables.	These invariables are to be built in the strategy.	The strategy is based on the existence of such invariables as indispensable resources.
Quality Invariables C	Such type of invariables exists because of the cognitive basis of the method.	Such type of invariables exists because of the cognitive basis of the method.	These invariables are basic preliminaries of the strategy.
Quality Operators A	It does not apply because of the absence of operating modes.	Few operating modes are to be monitored; mainly: action planning, control system, reporting format, evaluation...	Many operating modes will have to be monitored: problem adequacy, project planning, reporting system, auto evaluation process, evaluation…
Quality Operators B	A grid based evaluation process will cover few items related to the used techniques, to the course content and to the instructor's performance.	Many grids will be used to assess the different phases of the strategy.	Many grids will be used to assess the different phases of the strategy.

TABLE 2. Analysis of Results

Comparing the two tables gives an exact idea of why the PBL strategy's results were the best pedagogically speaking. A student-centered set of techniques is not sufficient to ensure a sound knowledge acquisition, or to help in developing the students' skills, or to create knowledge integration. The cognitive approach was very supportive of the two other experimented strategies, but the PBL strategy was more efficient because it was able to satisfy more criteria and was better suited for monitoring and assessment.

6. CONCLUSION

Back to the basic question, one would expect such results because of the similarity between the cognitive based methodology and the PBL strategy. We tried to advocate and to prove that this strategy is based on a solid

theoretical background and is flexible enough to be implemented even on a reduced scale. But it is crucial to stress the fact that this strategy, with its strong methodological basis that we tried to establish, may be implemented not only at the university level, but also at the earliest stage of schooling. I will dare to say, the earliest such a strategy is implemented, better it is for the student's development. But as a result we may say also that such strategy will question the classical curriculum design process mainly in terms of contact hours, interdisciplinary programs, and inter-relation with real life situations. New experiments and researches are needed to ensure a better integration between the cognitive approach and the PBL strategy for the sake of an enhanced quality of the educational system.

References

[1] Brown, S., Collins, A., & Duguid, P., *Situated learning and the culture of learning*. v18 n1, pp. 32-42, Jan-Feb 1989. <http://www.exploratorium.edu/ifi/resources/museumeducation/situated.html>.

[2] Engeström, Y., (N.D.). < http://www.edu.helsinki.fi/activity/people/engestro/>.

[3] Miao, Y., *Design and Implementation of a Collaborative Virtual Problem-Based Learning Environment.* Université de Darmstadt, 2000. <http://elib.tu-darmstadt.de/diss/000086/thesis.miao.PDF>.

[4] Nahas, G., *Conceptualisation et Langue d'Enseignement*. Thèse soutenue à l'Université René Descartes, 1994.

[5] Nahas, G., *The cognitive approach as a basis for enhanced curricula*. In James E. Groccia & Judith E. Miller (Eds.), *Productive University* (pp. 227-239). Anker Publishing Company, Inc.. Bolton, USA, 2005.

[6] Newman, F., & Holzman L., *Lev Vygotsky, revolutionary scientist*, London N.Y., Routledge, 1993.

[7] Norman, G.R., and Schmidt, H.G., *The psychological basis of problem-based learning: A review of the evidence.* Academic Medicine 67, 557-565, 1992.

[8] PedagoNet, (N.D.). *Grille d'analyse du scénario pédagogique/enseignement stratégique*. 14 août 2006 <http://www.pedagonet.com/other/grilles2.htm>.

[9] Piaget, J., *Mécanismes perceptifs.* Paris, Presses Universitaires de France, 1975.

[10] Tuckman, B., *Developmental Sequence in Small Groups*. 2001. <http://dennislearningcenter.osu.edu/references/GROUP%20DEV%20ARTICLE.doc>.

[11] Vergnaud, G., *La Théorie des Champs Conceptuels,* Paris, La Pensée Sauvage, 1991.

[12] Vergnaud, G., *Psychologie et Didactique*, in La Psychologie scientifique et ses applications. Clermont-Ferrand, 1987.

[13] Vygotski, L., *The genesis of higher mental functions,* in The concept of activity in Soviet Psychology, J. W. Wersch, 1981.

[14] Vygotski, L., *Pensée et Langage*, Paris, Editions Sociales, Traduction française du texte russe de 1934.