ΣΟΦΙΑ–SOPHIA

DOI: http://dx.doi.org/10.18634/sophiaj.14v.2i.788

Linking mediated by learning based on eco-efficient projects

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Article Information

Received: December 01 of 2017
Revised: April 11 of 2018
Accepted: June 30 of 2018

How cite:
Ramírez, M.B. (2018) Linking mediated by learning based on eco-efficient projectsSophia, 14 (2), 60-72

ISSN (electrónico): 2346-0806 ISSN (impreso): 1794-8932

UNIVERSIDAD La Gran Colombia Fundada en 1951

Sophia-Education, volumen 14 issue 2. English version

Abstract

In Colombia, most universities that train professionals in chemistry prioritize their scientific training in a disconnected form with chemical processes and industrial chemistry, although 78% of chemists practice their profession in the industry, evidencing a high demand in that labor market (Ministry of Education, 2015). In the Eco-efficiency research group of Universidad Pedagógica y Tecnológica de Colombia, an educational innovation was developed for a competence-based training of chemists, called linking towards green chemistry. The linking was designed in terms of competence unit, based on metacognitive strategies of learning, evaluation and transfer; (it was) applied in the eighth semester of an Industrial Chemistry course, with pedagogical mediation of learning based on eco-efficient projects, and undertaken in an action research (Carr, 1988). It started with 19 generic competences proclaimed in the Alfa Tuning Latin America Project (2005-2013), and 16 specific competences, articulated with the twelve principles of green chemistry, in order to ensure the sustainability of the chemical process (Anastas and Warner, 1998). The purpose of the work was to evaluate the process of training by competences under the criterion of authentic evaluation and its results, referring to the relevance and effectiveness of educational innovation, formulated and executed around self-knowledge, self-reflection and self-regulation. The results, validated internally and externally, are evidenced by the semester production of 10-15 eco-efficient products submitted to the entrepreneurial process, with important acknowledgments both in the academic and in the productive sector.

Key words: eco-efficient PBL (problem-based learning), linking, science teaching, metacognitive evaluation, pedagogical mediation.

Introduction

In the 21st century, the complex educational process of the teaching-learning of sciences has generated sudden changes of approaches and paradigms, towards a more coherent and autonomous formation regarding the challenges of the frontier of knowledge, even with the vertiginous advance of ICT. The pedagogical challenge not only involves actions to verify, accredit and certify levels of knowledge reached by students, but to innovate productively and sustainably, through competence training and formative evaluation; which challenge students to confront real scenarios with cases, problems, good laboratory practices and social responsibility, demanded by interdisciplinary (fields), and the technological and multicultural changes of globalization.

From this pedagogical approach to science, the research group on Eco-efficiency and Natural Products of the School of Chemical Sciences of *Universidad Pedagógica y Tecnológica de Colombia* (UPTC, for its initials in Spanish) planned and executed an educational innovation called linking, whose purpose was the formation of a green chemistry professional (chemist), based on autonomous learning, metacognition (self-knowledge, self-regulation and self-evaluation), entrepreneurship and authentic evaluation, from the micro-curriculum of Industrial Chemistry, a subject taught in the eighth semester of the chemistry course.

In a professional program of Chemistry, industrial chemistry is not the point of arrival, but of multidisciplinary convergence, because it covers from the macroscopic study of natural phenomena and transport to the microscopic study of matter and its interrelations.

With little depth in the convergent interdisciplinary management in industrial chemistry, there can be generated dispersed results and students with spurious, diluted or fractionated background and knowhow. Instead, if depth and rigor provide adequate prospective scenarios, we can rethink the formation of a Colombian, eco-efficient, innovative and enterprising chemist.

The linking made in the ECQ-UPTC, evolved as an object of the doctoral thesis in Educational Sciences (Rudecolombia), carried out by the author, with the support of significant experiences transferred from the University-Business Center of the Autonomous University of Chiapas. Mexico.

Competences and autonomous learning. The experience of autonomous learning of green chemistry (sustainable) from the micro-curriculum of industrial chemistry, demonstrated over three consecutive years the acquisition of skills relevant to a process of training by integrated competencies.

The process implies that students understand and appropriate their learning as a multidirectional circuit, which generates social abilities, creative and critical thinking, in order to stimulate their analytical capacity of know-how, ethical, professional and sensitive, in their integral formation.

Competencies presuppose the incorporation of an active, collaborative work pedagogy, which promotes metacognitive development through meaningful project-based learning (Brooks, 2005, Ursache, 2013 and Nueno, 2009). Therefore, the linking is designed to empower a student responsible for an autonomous learning process and, under the direction of the teaching team, to characterize problems, to hierarchize the proposals to solve them, and to make decisions, thus acquiring degrees of responsibility and professional growth within of the scientific, cultural and socioeconomic context.

The Tuning Project for Latin America (PTAL-2007), concluded and defined the set of competences necessary for the formation of the chemist (or related careers). The generic or transversal competences, (initially 27), were refined and reduced to 19 (G1-G19); and for the year 2013, 16 specific competences were agreed (E1-E16). (Nueno, 2009).

The generic competences were grouped into four factors, associated to: learning process, social values, technological and international context, and interpersonal skills.

Competencies are linked to cultural, professional contexts, or to particular social conditions, such as the labor market. People develop competencies adapted to their environment, because not all human beings experience the same situations. The link between the competences thus understood, and the investigative method of facing reality, through the problem-solution methodology, promotes the formulation of projects, in this case innovative and eco-efficient ones, in order to solve complex tasks and challenges that motivate students to mobilize and integrate their knowledge, in an interdisciplinary way and in the real professional context; (one) that privileges training by competences (Perrenoud, 2013).

Entrepreneurship, another training link for integrated competences, involves qualifying and strengthening the attitude and aptitude of students, in order to promote new challenges, new projects, which allows them to progress gradually towards the achievement of the proposed result, to satisfy professional or business needs, which requires a vital element called entrepreneurial spirit.

Entrepreneurship can be defined as:

> To take human, creative actions to build something of value from practically nothing... it is the insistent search for the opportunity regardless of the available resources... it requires a vision, passion, commitment to guide others and the willingness to take calculated risks... (Timmons and Spinelli Jr, 2013: 116).

Consequently, linking the elements (links) immersed in metacognitive strategies, creativity and entrepreneurship is an integrating approach to empower a student responsible for the continuous process of interdisciplinary learning of science, who, under the guidance of the teaching team, characterizes problems, hierarchical proposals to solve them and take decisions, acquiring autonomy, responsibility and professional growth within the scientific, cultural and socioeconomic context.

The evaluation of the metacognitive process has a dual purpose, to privilege students' knowledge about learning and strategies for feedback (continuous improvement); in addition, it provides trainers and the institution itself elements to understand and reorient their current pedagogy, consistent with the metacognitive thought of its learners.

From the operative point of view, the evaluation should be framed in a qualitative approach and meet the characteristics of authentic, continuous and integral evaluation, as a propaedeutic function and as a comparative method, in order to face similar professional scenarios. As a consequence, there should be assigned tasks *placed at* the students, of a practical nature, that exploit their initiative and creativity to face problems, using methods, techniques and equipment, in a competent and methodical manner, for the most pertinent resolution; that is, in the most reliable and realistic conditions in a physical context (Díaz, 2013 and Perkins, 1997).

The evaluation focuses its attention on learning; therefore, the nature of learning is the object of the evaluation, and it aims to integrate the results, the knowledge society, inter-disciplinarity and complexity. The continuous formative evaluation allows students to perform their self-assessment, review and contrast their learning, with another educational and professional context, called the use of knowledge (Perkins, 1997).

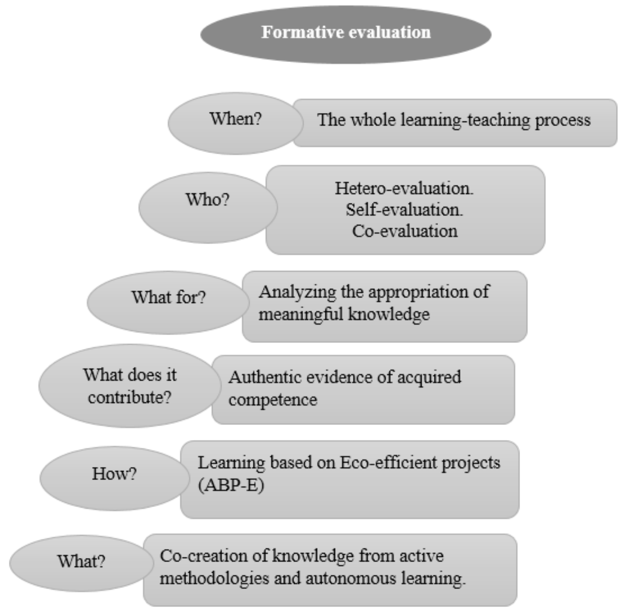
The binomial learning-evaluation incorporates independent elements, but (they are) not excluding, with reciprocal incidence; which, in addition, affect favorably self-esteem and motivation.

According to Monereo (2009), authentic evaluation is characterized by assessing especially the decision process necessary to solve a complex problem, in which different knowledge and skills must be activated and applied in coordination, in order to demonstrate the essential strategic ability to self-regulate one's behavior and adjust (oneself) to unexpected changes. This evaluation has three focuses: the non-formal evaluation (*alternative assessment*), performance assessment problem-based assessment. The characteristics of the formative evaluation modality are shown in figure 1.

The relevance of Project-Based Learning as a mediator in students' metacognitive process favors its approach to the professional context and the target market; however, a thin line can be inappropriately traversed and biased to training processes for work as a technician or technologist, rather than a professional in chemistry. This is avoidable when the levels of competence (know-how) are planned correctly, the different degrees of professional immersion (proposals and projects) to be developed; being careful of not falling into the resolution of irrelevant or artificial problems, whose only reference is intra-academic.

The scenarios of this active pedagogical-didactic must be planned minutely, in order to intervene well-documented real situations, or with access to it (Mills and Treagust, 2013), avoiding to approach insufficiently contextualized problems, which evade the complexity and uncertainty of the conditions and requirements of real professional situations.

Figure 1. Characteristics of the authentic metacognitive evaluation



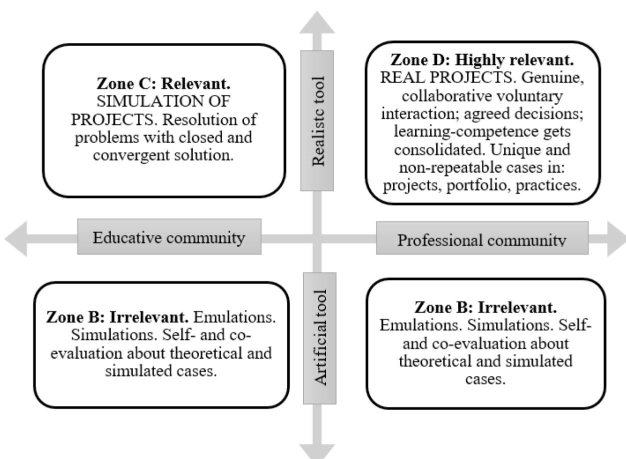
Source: own elaboration, adapted from (Monllor 2012, 2013).

The success of an authentic evaluation, applied to metacognition with real problems lies in the fact that the teaching team shares with students the evaluation criteria of each of the different competences, with the purpose of internalizing and applying them autonomously and ethically. At all times, it is intended that the effective solution of the real and relevant problem (close to real situations) be convergent and closed, in order to avoid dualities, ambiguities or asymmetries; whose relevance and coherence be tangible, measurable and demonstrable, for the target market (academic, professional, business) and the beneficiary community (Monllor 2012, 2013). There are evaluated the ability to combine resources and mobilize them in a context, knowing how to learn, understanding and transferring, and learning to learn.

Two-dimensional analysis of the competence assessment process developed by (Monereo, 2009) proposes two axes of action as a reference in the same assessment tool by competence, determining four quadrants, according to the level of relevance (Figure 2). Zone D stands out as very relevant, due to its relationship with the educational-professional community and its realistic character; which is concomitant with formative mediations of the *project* type (ABP) or *resolution of cases*; relevant elements with the *linking methodology*, object of this work.

Change as a response to the quality of the process. Competence-based learning is a commitment to and for change. There are still present vestiges and lags of traditional education, where students are passive subjects of their professional training. Instead, a competence-based training is integral, professional, personal and dynamic, but also by a binding education with life in a complex, competitive and changing environment; where it is always worked as a team and collaboratively.

Figure 2. Areas of relevance in the evaluation by competences.



Source: Prepared by the authors, adapted from Monereo (Monereo, 2009).

Resistance to the change of methodology of formation, from passive pedagogy (of transmission) to active pedagogy for understanding, makes opaque or invisible the process. However, resistance must be overcome by incorporating communicative strategies, in order to strengthen the process and commitment, in pleasant collaborative learning environments, mediated by ICT.

In the learning of sciences, these dynamic environments are important for *learning to learn*, because they incorporate databases, verifiable with scientific literature, and simulators of processes and molecular simulation for chemical analysis; These tools of soft but relevant technology are vital for students to develop critical thinking, in the comparison and contrast of results in spectroscopic tests against the digital libraries available in robust equipment.

While for Diaz-Barriga (2013): "Formative evaluation offers elements to analyze the way in which the established learning sequences work and, at the same time, allows to build some evidences that will be taken into account for the summative evaluation or certification"; for Monereo (2009):

> Evaluation, applied in this way, is a true authentic evaluation, since it is characterized by assessing especially the decision process necessary to solve a complex problem, in which different knowledge and competences must be activated and applied in a coordinated way, and where there must be demonstrated the essential strategic capacity to self-regulate one's behavior and to adjust to unexpected changes, justifying later actions (p.12).

In short, the complexity of training requires the combination of effective criteria and instruments that allow us to understand all its dimensions and promote evaluation, as the end of the training process.

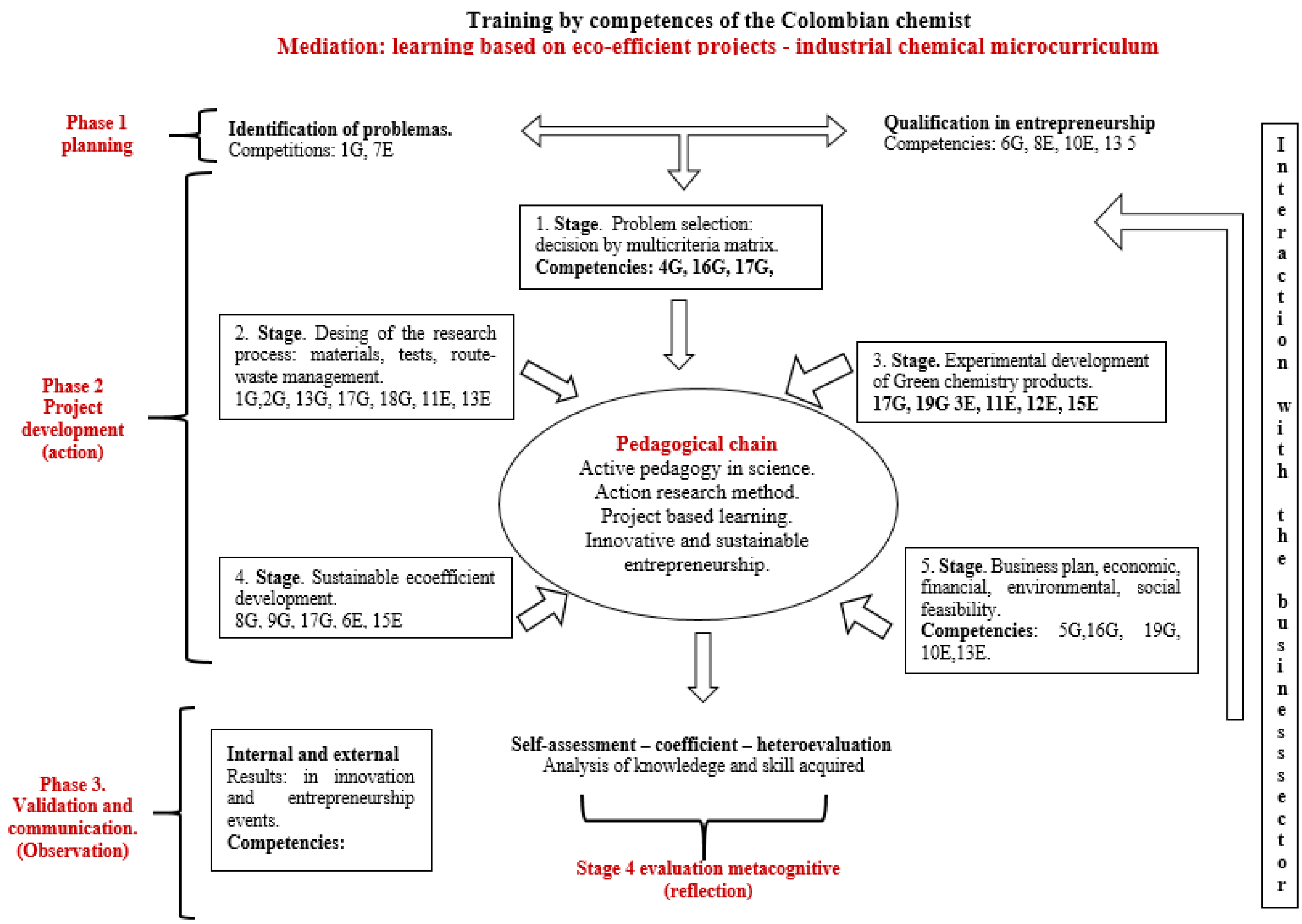
Materials and methods

It was applied the method of Action Research (applied in the educational community of ECQ-UPTC). It was developed mediated by the ABP-E methodology; it was applied in three moments: learning outcomes (acquisition of skills); the quality of the processes, taking into account the learning community (educational results), and the authentic evaluation as a tool to manage learning and guarantee the quality of knowledge, skills and attitudes, applicable in an active and efficient way (Hernández and Baptista, 2005), in order to solve real problems (experiential learning) in real professional contexts.

Research Phases

The Action Research (AI) process was developed in four phases: planning, action, observation and reflection. Starting from the scenarios described in figure 3, the four methodological phases were disaggregated into different stages, enhancing the generic or transversal (G) and specific (E) individual competences developed by students as cognoscente subjects and co-investigators of the process; under strict compliance with the 12 principles of Green Chemistry (PQV).

Figure 3. IA-E process for training by generic (G) and specific competences (E)



Source: self-made, incorporating the competences according to the PTAL-2013 (Nueno, 2009).

The reflection phase (metacognitive evaluation) allows generating the relevant criteria for re-addressing for the next cycle (new semester), according to the results of the training process.

One of its components is hetero-evaluation, whose central axis is the development of the project and the analysis of the solution product, (a) metacognitive strategy that constitutes a micro-curricular development of maximum relevance in the transition of roles, of a student at the end of the career towards a professional in a real context (Monllor, 2013).

In this innovation, group and collaborative work may present weaknesses, due to lack of commitment or little access to ICT and advanced software tools, as well as robust technological equipment; vital for the motivation of students in collaborative learning environments, and for pulling a learning community in the previous semesters of the curriculum at the moment of linking (Monllor, 2013).

Phase 1. Planning

Identification of problems and qualification in entrepreneurship. Supported in a set of qualification workshops and methodological training, in order to identify real problems in context and situations with different degrees of professional immersion, where the impact on their environment be tangible.

Supported in pedagogical models by competences and training of entrepreneurs (Antón, 2013, Brooks, 2005 and Ursache, 2013), different situations (problem events) are analyzed, close to the real practices of the target professional community, discarding emulations and simulations.

Actions are taken to strengthen the competencies: *capacity for abstraction, analysis and synthesis (1G); and capacity for planning, design and execution of research projects* (7E), in order to formulate coherent and pertinent questions regarding the addressed problem (under the systemic analysis of the context), framed in the typology of problems: prototypical (innovation project) or emerging, coming from professional or cooperation networks (Monereo, 2009).

Sustainable solutions are favored, projecting an entrepreneurial spirit to create innovative companies, with which it is worked on competences: *commitment to their socio-cultural environment, mastery of chemical terminology, nomenclature, conventions and units; knowledge of other scientific disciplines that allow the understanding of chemistry, the ability to act with curiosity, initiative and entrepreneurship* (6G, 8E, 10E, 13E).

Phase 2. Action: development of the eco-efficient project

- **First stage. Selection of the problem**. Decision by application of a multi-criteria matrix for the classification and selection of the research problem.

Analytical review of current literature -state of the art- in order to preliminarily identify if the subject and object has been little studied and/or little investigated; favoring common and novel problems, analyzing in depth the scope of the proposed solutions and the satisfaction of the target market.

During the formulation of the problem and the proposal to create a product derived from research, the competences are acted upon: *skills to search, process and analyze information, ability to motivate and lead towards common goals, ability to work in teams, ability to act with curiosity, initiative and entrepreneurship, ability to make decisions* (4G, 16G, 17G, 13E, 14G).

Evaluation No.1. Divulging the characterized problem. Approach and hypothesis contrast, initial conceptual maps, strategies, expected results regarding the characterized problem.

- **Second stage. Process design**. Analysis and construction of process diagrams, planning of: materials, critical path, number of tests; route for managing waste and polluting loads. The competences are: *capacity of abstraction, analysis and synthesis, ability for learning and updating, skills in the use of information technologies, ability to teamwork, ability to organize and plan time, skills in monitoring through the measurement and observation of chemical properties, events or changes, and their collection-documentation in a systematic and reliable way, ability to act with curiosity, initiative and entrepreneurship*. (1G, 2G, 13G, 17G, 18G, 11E, 13E).

Evaluation No. 2. Process feedback. Divulging of partial advances of the process. Each group reflects on the transformation given to their project and evaluates it in a self-critical way, taking into account the achievements reached in the third stage. It is interacted with contributions, in order to support and co-evaluate their peers.

- **Third stage**. **Experimental phase**. Development of protocols, routes, tests, physicochemical, microbiological, sensorial and chemical analysis (qualitative and quantitative). The developed competences are: *ability to teamwork, ability to act in new situations, ability to interpret and evaluate data derived from observations and measurements related to theory, skills in monitoring through measurements and observation of chemical properties, events or changes, and their collection-documentation in a systematic and reliable way, ability to act with curiosity, initiative and entrepreneurship, mastery of good laboratory practices, ability to apply knowledge of chemistry in sustainable development*. (17G, 19G 3E, 11E, 12E, 15E).

Evaluation No. 3. Feedback of the results. Evaluation of experimental competence in the research process, planning versus execution of the work plan, from the scenarios of learning and sustainable experimentation. It self-evaluates and co-evaluates how the situation was resolved. It was used the group critical discussion methodology proposed in Brooks (2005).

Progress evaluation No. 4. Review of the teaching team responsible for the course.

Development based on the monitoring of the groups, on the identification and characterization of the problem, identification of variables, eco-efficient experimental design, data collection.

Emphasis is placed on the processing of associated quantitative and qualitative data, in order to consolidate the relevant information, the handling of replicas, reprocesses and analysis of errors and uncertainties.

- **Fourth stage. Sustainable eco-efficient development**. Calculation of indicators and generated impacts. Environmental management plan for the probable polluting waste. There are reviewed the commitment, aptitude and attitude to manage and build waste treatment routes, in order to mitigate direct and indirect environmental impacts. The competences generated in this stage are: *social responsibility and citizen commitment, commitment to the preservation of the environment, ability to teamwork, ability to stay updated in the development of chemistry, skills to apply knowledge of chemistry in sustainable development*. (8G, 9G, 17G, 6E, 15E).

- **Fifth stage. Business plan**. Feasibility: economic, financial, administrative, legal, environmental and social analysis.

The active commitment of the group is observed in the ethical, legal and environmental values of society and the ideal environment of their work, integrating with social responsibility as a citizen and professional. Indicators are developed by area to determine if the project is feasible, desirable and achievable. The competences are: *oral and written communication ability, capacity for teamwork, ability to act in new situations, knowledge of other scientific disciplines that allow the understanding of chemistry, ability to act with curiosity, initiative and entrepreneurship*. (5G, 17G, 19G, 10E, 13E).

Phase 3. Observation: validation and communication

It is the visibility window of the obtained results, carried out through oral and written communication actions, with descriptive scientific language, analytical criteria and technical standards, with sufficiency in argumentation, proposition and discussion of results.

- **Internal validation of results**. It is organized the interaction of the main participant, the entrepreneur-researcher, through divulging in the UPTC learning community.

- **External validation**. It is done with the business community of the area of influence through innovation, entrepreneurship and business rounds, with the investors invited by the event, for the evaluation, awarding and financing of the winners.

In this phase, these competences are enhanced: *oral and written communication skills, ability to work in international contexts, mastery of chemical terminology, nomenclature, conventions and units, knowledge, application and advice on the legal framework in the field of chemistry*. (5G, 12G, 8E, 14E).

Phase 4. Reflection: metacognitive evaluation

It is the permanent and integrated activity carried out horizontally and vertically on the training process. The evaluation instruments are subjected to the internal validation process, through the application of the Alfa Cronbach Test and the SPSS version 23 software.

- **Hetero-evaluation**. Actions applied by the teaching team, participating entrepreneurs and jury evaluator in regional entrepreneurship events (external validation). There are evaluated the argumentation of the work, tangible-sustainable solution and learning through the process (endogenous validation).

It is an action that complements the self-evaluation and co-evaluation made in each advance. The teaching team applies a validated instrument, which is structured with a Likert scale in the range of 1-5, which allows assessing the level of acquisition or achievement of the competition: 1 (not reached), 2 (poorly), 3 (in limited form), 4 (in outstanding form), 5 (totally).

The evaluation instrument is of individual application, and its purpose is to determine, according to students' own perception, the level of competence acquisition, result of the developed educational process.

- **Self-evaluation**: It is an activity in which students may introduce elements of bias or asymmetry regarding a value judgment, issued by sympathy, affinity, friendship, conflict of personal or common interests.

The proposed annexed instrument, validated and applied by the author, is supported in eight metacognitive dimensions of autonomous learning. Each one has five competences, for a total of 40 evaluated competences. The dimensions are: interpersonal skills, ability to teamwork, analysis of conceptual relationships, management of sources and information analysis, logical-conceptual and critical thinking, ability to adapt to pedagogical innovation (in order to assess the relevance of the participant with the methodology IA), verbal communication skills, and written communication skills.

The quantitative evaluation is based on a score through the Likert Scale (1-5), about different perceptions related to metacognitive strategies for autonomous learning, incorporated into: organization, self-regulation (Díaz F., 2003), metacognition (Tovar , 2005), time management, effort regulation, peer learning (Monllor 2012, 2013 and Ursache, 2013), and search for help (Antón, 2013).

- **Co-evaluation:** It complements the longitudinal formative evaluation and is carried out qualitatively; however, a universal format instrument is applied to collect qualitative-quantitative elements from their peers, in which 5 strengths and 5 weaknesses of the respective project are recorded. In the same instrument, the group performs n-1 evaluations.

Design. *Type of research*: descriptive and relational, in order to determine the conceptual and applied links between the different dimensions, categories, variables and strategies.

Population of the study: Eighty (80) students, who studied the chemical industrial course in the eighth semester of the Professional Program in Chemistry of the UPTC.

- *Target group*: received intervention with the PBL-E, an active methodology that is very relevant, realistic and close to the professional community (figure 2), and with authentic competence assessment, as a guarantor of the learning process (training).

- *Control group*: the chair of industrial chemistry was taught through the traditional passive method (receptor agent), without qualification in ABP or entrepreneurship. Students receive a predetermined problem from the teacher, for its resolution, under a set of requirements, a laboratory guide and the syllabus of the subject. Its evaluation is of summative type, at the end of the process (hetero-evaluation).

Type of study: Longitudinal, through six academic semesters, during the years 2014 to 2016.

Instrumentalization: The methodology links the ABP learning links and entrepreneurial training, which will articulate the Action Research elements, as well as the pedagogical and didactic elements of the entrepreneurship training model.

Operationalization: Projects are planned and executed by pairs of students freely organized, without criteria of association, at free will. Each group identifies and characterizes a real problem, delimiting its contribution to an innovative, green and eco-efficient solution, relevant to the principles of Sustainable Development, the principles of sustainability and competences in green chemistry (Valiente, 2016).

The results allow semi-annual reflections (background of accumulated experiences), in order to redefine improvement actions with the next biannual cohort, and to consolidate the learning community.

The group builds a portfolio, in order to record the physical, photographic and filmic evidence of its progress.

Interventions: Action Research is a qualitative research method. It is important to note that in the development of the ABP-E methodology, it corresponds to a relational analysis with analytical categories. In order to develop the goal of metacognitive assessment, supported measurements are applied with numerical parameters, especially for data processing.

Statistical analysis: For qualitative validation, the criteria are analyzed and evaluated and the judgments (answers, opinions, speeches) are assigned on the quality of the products and the training process.

The statistical treatment is carried out by measurements or scale metrics, grouping the scores (item value) by modes (visual groupings), by means of the statistical technique of "attitude analysis" (by categorization of variables).

For each item, the number of responses in the respective category (1 to 5) is tabulated.

The weighted average of each item is obtained (as a value, not as a statistic), using:

For the analysis of information of the eight metacognitive learning dimensions, the scores of each item are organized in the following "visual groupings":

1-2 = very unfavorable attitude,

Greater than 2, up to 3 = unfavorable attitude,

Greater than 3, up to 4 = favorable attitude,

Greater than 4, up to 5 = very favorable attitude.

The results are tabulated and processed using Microsoft SPSS 23 software, whose "variable view" are 40 and the four groupings; while, the "data view"... The values obtained are presented, where the column "value" of the item is the quantifier that allows to locate the item (variable) in the respective grouping (attitude).

Results

For the target group, the metacognitive dimensions produced the following evaluations in the units of the quantitative scale 1 to 5, mean value and standard deviation, respectively: interpersonal skills (4.64 ± 0.34), teamwork capacity (4.56 ± 0.39), analysis of conceptual relationships (4.61 ± 0.14), source management and information analysis (4.63 ± 0.15), logical-conceptual and critical thinking (4.37 ± 0.46), ability to adapt to pedagogical innovation (4.39 ± 0.12), verbal communication skills (4.22 ± 0.18), and written communication skills (4.13 ± 0.13).

Regarding the acquisition of competences, in their qualitative order, they were: in knowledge and interaction (characterization) of the relevant problem; autonomy and personal initiative; social and environmental competence; learning to learn; verbal communicative competence (linguistic and audiovisual).

The evaluation of the learning of the target group is related to the cognitive and attitudinal transformations that enabled the autonomous development of interdisciplinary competences, from the metacognitive perspective (Tovar, 2005) and the solution of problems through entrepreneurship in sciences (Flavell, 1976).

In terms of products generated by the binomial classroom-laboratory, the productivity of the linking is evident in the innovative eco-efficient products developed by students: bioplastics from residual vegetable biomass, polymeric materials, paints from waste tanneries, fragrances from extracts of regional aromatic plants, craft beer based on tubers, encapsulated aromatic infusions, antibacterial liquid soap, liquid soap from biomass fatty waste, biopolymers, creams based on natural products, a disinfectant for dogs, an organic insecticide based on chili, natural additives for the preservation of meat, among others.

These eco-efficient products, developed by the new generation of Colombian chemists, were recognized and evaluated by external peers in five regional innovation, entrepreneurship and research events. The acknowledgments are evident in six awards: two for biotechnological innovations, two for creativity and two for technology contracts, one with *Silicon Valley Travel* Latin America.

Through an analysis of variance (ANOVA), at a level of significance of 5%, there were significant differences between the mean values of acquisition (qualification) of competencies between the target group and the control group.

In the quantitative order, the evaluations of the course of the target group exceeded that of control by 22.2%, evidencing greater productivity and demonstrating the benefits of educational innovation training by competencies, based on the metacognitive strategy mediated by Learning Based on Eco-efficient Projects and entrepreneurship.

The link of entrepreneurship was incorporated as a way of thinking, reasoning and acting, to find opportunities with green focus, leadership and commitment, perseverance, self-confidence, as well as ability to teamwork (Nueno, 2009).

After reflection (evaluation) every six months, students of the new cohort have moved the frontier of applied knowledge towards a position of imbalance, where convergent thinking allows them to manage more refined analytical processes, which instead of transcribing a business plan, promote new behaviors and competencies, as well as the development and use of new tools of green chemistry, in order to improve the reflective and longitudinal analysis of the business fabric, in a socioeconomic system, that still does not find a defined role for a graduate in chemistry.

However, the results show, qualitatively and quantitatively, the irruption of managerial leaders of a coherent and responsible knowledge with sustainable development, capable of intervening scenarios of the productive sector, launching bio-companies with application of clean industrial organic and inorganic chemistry, with environmentally sound solutions, relevant to the principles of green chemistry.

Discussion

The evaluation of learning of the Target Group is referred to the cognitive and attitudinal transformations that made possible the autonomous development of interdisciplinary competences, from the metacognitive perspective (Tovar, 2005) and the solution of problems through entrepreneurship in sciences (Flavell, 1976).

Regarding the acquisition of competences, in their qualitative order they were: in knowledge and interaction (characterization) of the relevant problem; autonomy and personal initiative; social and environmental competence; learning to learn; verbal communicative competence (linguistic and audiovisual).

The metacognitive evaluation compared between the Target Group GO vs. GC Control Group, conducted by the teaching team and using the same Likert Scale produced the following results on the acquired competences: Not reached (GO = 0%, GC = 3%), poorly reached (GO = 2 %, GC = 8%), reached in a limited way (GO = 7%, GC = 74%), reached in an outstanding way (GO = 87%, GC = 15%,); completely reached (4%, GC = 0%). The averages weighted by the Scale were: GO = 4.3 and G.C = 3.15.

In the linking, students have the opportunity to learn in a dynamic and incremental way new approaches to entrepreneurship, in terms of innovation, creativity, adaptation and cognitive development.

Conclusions

Linking is an innovation in the university learning of sciences in Colombia, because from emancipatory training by competencies and the metacognitive (authentic) evaluation of the process, it promotes autonomous learning in the field of eco-efficient innovation with entrepreneurship.

The eco-efficient chemical production competition, with entrepreneurial aptitude, projects a person trained in sciences, with self-esteem and corporate social responsibility, of promising professional positioning in the regional and national industrial field; for their ability to lead environmentally sound production processes and work as a team to solve real prototypical problems.

The short-term result will be a graduate in chemistry with a profile and leadership in research and innovation, autonomous, with regional relevance in the use of natural resources and residual vegetable biomass.

The educational innovation incubated in the UPTC aims to be a national pilot (project), to be scaled in the different chemistry training schools, in the applied levels of undergraduate and master's degree programs, redirecting entrepreneurship towards new lines of research in bio-enterprise to intervene in the application of biotechnological solutions with high added value. In addition to knowledge management, it constitutes a tangible contribution for the graduates to apply contingent co-financing and exceptional tax benefits derived from Law 1429 of 2010 (first job), aimed at young graduates who create new and small businesses, especially with technological bases.

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