Obtaining products in Chemical Engineering through Reproducing an Environment of Innovation in the Classroom

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Abstract: *Creativity and capacity for the implementation of products are today part of the bases of university education, aimed at training professionals who possesses skills and competencies to contribute to the development of the society in which they live. The teaching-learning process in traditional university education has used strategies that place the student as a receiver of information which is conceptualized as knowledge. This type of training has been shown to have deficiencies because in present days there is a global access to information, which can be found through different media, mainly electronic. This makes the main goal of education the development of the capacity to generate solutions in obtaining products and services that can meet the needs of people, known as development of skills or know-how. In this paper, various products obtained through the application of "Reproducing an Innovation Environment in the Classroom" (RAIS) in courses in the curriculum of Chemical Engineering at the Universidad de los Andes are presented. These include personal care products such as soaps, sanitizers, cosmetic creams, sun and lip balms; cleaning products; and foods such as liqueurs and beberages. This strategy has enabled students to develop creativity and entrepreneurial skills fundamental in their succesful professional life. It has been shown that this strategy also interconects the course objectives with the development of a product, making available an implementation of product engineering in Chemical Engineering Education.*

Introduction

The current debate on education has generated an important theoretical production and a cumulative experience that has led to intelectual exchanges of all kinds. Reflections on this subject at the international level have allowed a multidimensional approach from different perspectives to what we conceive as education and its purpose (UNESCO's documentation is a good example of this). Not only the conception we have of it is object of study, but also the context in which it is framed and the reality that it must face in the coming years. In this sense, education faces new and changing challenges (Morin, 2002), to which it must respond from its own reality. This leads to a changing enviroment that needs the constant update of knowledge (Morin, 2000) that validates it and makes it effective. Currently education thinkers focus on how to articulate and organize knowledge, in order to be able to recognize and know the problems of the world and to give them adequate and pertinent answers and correctives. This is what UNESCO (1998) has agreed to call "the orientation [of education] to the long-term relevance" that is achieved when education is increasingly at the service of society, with better articulation with their problems and those of entrepreneurial work.

When this new vision of education is adopted, it is possible to understand that educational practices and teaching strategies must be modified in order to overcome the mere cognitive mastery of the disciplines and foster the development of knowledge, skills, communication, creative and critical analysis, teamwork, the ability to undertake projects, and the combined application of traditional or local theoretical and practical knowledge with state-of-the-art science and technology. These new objectives of education arise, motivated mainly by the current world reality: the Information and Communication Society (ICS) in which we live. In the ICS, the democratization of the internet, open content and collaborative environments, give the possibility not only of consuming but of creating information and participating in it, among other aspects, changing the ways of accessing, developing and communicating knowledge. These new ways of relating to knowledge have important implications for education, as they mean new ways of learning, new spaces, greater flexibility and more personalization of the learning process.

As far as higher education is concerned, this reality forces us to transform our conception of teaching and learning and, therefore, to update and rethink the academic processes within university institutions. Reform in educational practices becomes more and more urgent, when the deficiencies and failures of the prevailing model are evident. This reform requires profound curricular transformations, and although such transformations are a long and slow road, the teaching action in the classroom does not need to wait for them to be updated. We would rather say that it is from the classroom, the place from which the process of educational change should begin.

In this sense, the authors, a group of professors of the School of Chemical Engineering of the University of Los Andes of Mérida, Venezuela, have been interested in proposing and carrying out new educational actions, aimed at forming competencies, develop potentialities and promote attitudes committed to the professional and social development of students. In the teaching of different key courses in the Chemical Engineering program, the RAIS strategy "Reproduction of an Innovation Environment in the Classroom" has been implemented (Marquez, et al., 2016). According to this strategy, students learn by developing an engineering product. Knowledge is built around the execution (manufacture) of a final product, whose choice depends on the students themselves, mediated by the experience and curriculum guidelines indicated by the teacher. The students are motivated and oriented to fully handle the course and also general knowledge, that are necessary for the successful development of the project.

In this paper we present some of the most illustrative experiences of the RAIS pedagogical scope in the courses Physicochemistry for Chemical Engineers and Laboratory of Industrial Chemistry of the Chemical Engineering School of the University of Los Andes. Highlighting how the traditional academic objectives of teaching (focused on the teaching of conceptual and procedural contents) with broader objectives through the development of a product are achieved, which aim to discover, awaken, and increase the creative possibilities and the capacity of students to take entrepreneurial initiatives, fundamental conditions for the professional, personal and social development of young people (Delors, 1996).

Methodology

What is RAIS?

RAIS is a teaching strategy that seeks to integrate learning theories by construction and discovery, cooperative and collaborative learning, and project learning, with the reproduction of an innovation environment with the dynamics and characteristics that are presented in an entrepreneurial setting (Sandia, Et al, 2011a). It is a didactic proposal oriented to transform the traditional process of teaching and learning, based on the explanation and transfer of knowledge, in a process based on the application and the integral and pertinent management of knowledge.

RAIS, originally called "Reproduction of an Industrial Environment in the Classroom", was created and developed by Sandia et al. (2010) at the Universidad of Los Andes, after a continuous demonstration of a high level of demotivation among the students of the Faculty of Engineering. Subsequently, the word industrial was changed to "Innovation", to account, on the one hand, for a wider universe of applications, and on the other, the authentic creative process that takes place in the classrooms where it is developed. Sandia and coauthors propose the incorporation in the teaching-learning process of activities for the formation of competences related to creativity and entrepreneurship, which contribute to develop a favorable attitude and a disposition to learn, fostering academic success and the achievement of comprehensive vocational training. The RAIS strategy has been used in different courses and subjects of different engineering careers. The published works (Sandia et al., 2011a and b; Gutiérrez et al., 2015; Márquez et al., 2016) are an excellent example of the variety of proposals that can be made and of the flexibility of adequacy and application.

RAIS is based on the productive and effective working environment characteristic of a entrepreneurial setting. The strategy transforms the classroom into a set of start-ups, aimed at generating a final product. The development of the selected product requires the study, understanding, integration and application of a wide range of knowledge and their intrinsic relationships, where both the knowledge inherent in the subject that the students are taking, as well as those that allow the successful execution of the project are taked into account. In this sense, RAIS becomes an effective platform to implement the integration of knowledge and disciplines to develop a product. For a better description of the methodological strategy, its fundamentals, its components and gears, as well as the evaluation strategies, the reader is advised to refer to the previous works of Sandia et al. (2011a and b) and Marquez et al. (2016).

How is RAIS being implemented for teaching in Chemical Engineering?

One of the advantages of the RAIS strategy is that, despite the key and indispensable components necessary for its implementation, and therefore, to ensure the achievement of the objectives, RAIS is a flexible and adaptable strategy, both for the requirements and curricular conditions of the course and the characteristics of the group of students (interests, previous knowledge, expectations, availability of time and resources, ease of access to information, among others). Thus, every RAIS course is based on the following components or steps: establishing clear teaching-learning objectives, organization of the set of companies (work teams), selection of the products to be developed, definition of roles and functions to be fulfilled by both students and the teacher, scheduling activities (product execution plan), meetings and partial reports, and specifying the strategies that will be used for formative and summative evaluation of the process.

The above steps are common to all courses based on RAIS. The particularities, which are given by the nature of the subject and by the group of students, differentiates one RAIS experience from another. In the case of the Chemical Engineering courses where the strategy has been applied, we want to highlight some aspects that have been adapted according to the possibilities and limitations of the courses:

- Different products per company, proposed by the students.

Unlike previous experiences (Sandia et al., 2011b and Gutierrez et al., 2015), for the courses Physicochemistry for Chemical Engineers and Laboratory of Industrial Chemistry, each company proposed several possible products to be developed. With the guidance of the teacher, the students had to select the one that allowed the most optimal fulfillment of the cognitive, procedural and attitudinal objectives proposed. The participation of the students in this stage, favored the diagnosis, a primary educational element in educational planning (Diaz Barriga and Hernández, 2002), which allowed the curricular content to adapt to the interests and needs of the young people. On the other hand, it allowed the activation of previous knowledge, coupled with the search for related and relevant information. From the constructivist approaches (Bruner, 1959) and cognitive theory (Ausubel, 1963, Ausubel et al., 1978), essential for the construction of knowledge and the acquisition of meaning to acomplish an integration between the new Information and pre-existing conceptual structures.

- Goals and schedules adjusted to each company.

When establishing a single product for the course, objectives and work planning is common for all companies. In our case, each company presented varying requirements and levels of complexity (within an average range), which depended on the product and the group of students. This situation demanded that the objectives and schedules should be adjusted to the conditions of each group. In spite of the difficulties that this variety of cases might entail, we believe that it simulates more closely the global and complex reality (Morin, 2002) that students in training will face tomorrow. RAIS, in its conception, seeks to reproduce from the classroom this reality "from the outside", showing that any aspect of this "outside" reality implies a context of its own, which can and should be approached from different perspectives. The contextualization and relevance of the process of study, design and elaboration of the product, and consequently, of the knowledge and the way of approaching them, is another important adaptation to highlight in our work.

- Broader interconnection of knowledge from other disciplines.

As a consequence of the previous point, the variety of products and fields of application, generated a greater wealth in contents and extracurricular knowledge. The interaction between groups during the development of the process, and the final presentation of the projects, allowed all students the access to this wealth of knowledge. We believe that through this way of implementing RAIS, students can form a broader and global vision of the scope and usefulness of the knowledge acquired, and therefore, will have the opportunity to establish greater relations of meaning that promote the positive modification of their behavior and attitude towards professional life.

- Strengthening skillsand competencies for experimental laboratory work.

The particular nature of the knowledge area of Chemical Engineering offers the possibility of developing both cognitive and procedural aspects related to the transformation of raw material into products of greater value, utility and versatility. The experience at the undergraduate level, of developing a product based on technical specifications, in a set time and as a result of a laboratory procedure, is an ideal scenario for learning. In this "controlled" environment, it is possible to promote the specific development of skills and competences, to encourage self-confidence, and to strengthen decision-making capacity in practical laboratory work. This learning will have a positive effect on the future performance of students in all kinds of jobs, especially those involving practical laboratory or production work in a company.

- Promotion of a healthy and proactive digital culture within the framework of the ICS.

As a final part of the work plan for obtaining the product, the publication of the completed project of each of the companies with completely free access on the Web was established. In the Information and Communication Society (ICS) in the that we are living, are generating new ways of accessing, developing and communicating knowledge. We consider that the task of publishing the works produced by the students themselves allows them to become aware of several important aspects: (a) that they are not only information consumers, but also creators and participants; (b) that knowledge must be oriented (being useful) and must be able to be applied in the resolution or satisfaction of the needs of society, otherwise it has no value to communicate it, because (c) the relation of the learner to the world must be authentic, identifying the contributions that as a citizen can offer to that world; (d) that today's society is not restricted to the physical limits of its closest environment, but extends to the planetary community, and consequently, (e) that the solutions and proposals of "here" may also be useful "there".

Results

The RAIS strategy was applied in several courses of the School of Chemical Engineering of the University of Los Andes, during the period 2010 to 2014 (Márquez et al., 2016). This report shows the work done in two of these courses: one theoretical, Physicochemistry for Chemical Engineers (FIQ); and another practical, Laboratory of Industrial Chemistry (LQI). Between the two courses, and in the two opportunities in which RAIS was applied in them, a total of one hundred and twenty-six (126) students were attended. Table 1 shows the particular characteristics of each course.

Table 1 Characteristics of the courses studied

Course	Semestre	Nº de estud.
Physicochemistry for Chemical Engineers *Theoretical course* *6th semester* *6 h / week* *Objective: To introduce the conceptual development of physicochemical phenomena and their importance in Chemical Engineering*	B2010	49
	A2013	37
Laboratory of Industrial Chemistry *Practical course* *7th semester* *4 h / week* *Objective: To handle the practical Industrial Chemistry and its applications in Process Engineering*	B2011	20
	U2014	20

The application of RAIS in both courses was oriented for obtaining an experimental product by company, following the same general objective, structuring of the work in four (4) phases, strategies and evaluation criteria, for a lapse of sixteen (16) Weeks (Table 2 in Márquez et al., 2016). From each course, the most representative projects were selected, as shown in Table 2 of this paper.

Table 2. Selected products developed with RAIS*

Physicochemistry for Chemical Engineers	
B2010	**A2013**
1. Liqueurs flavored by fermentation of sugar cane syrup 2. SPF 50+ Solar Protector	1. Homemade beer 2. Anesthetic cream based on eugenol
Laboratory of Industrial Chemistry	
B2011 and U 2014	

5. Beeswax products:
Healing cream
Moisturizing lotion
Lip balm
Soap

* Each of the projects are published with free access on the website: http://webdelprofesor.ula.ve/ingenieria/marquezronald/

Physicochemistry for Chemical Engineers:

Physicochemistry for Chemical Engineers is a key course in the basic and applied training of the Chemical Engineer, it integrates the subjects of Solutions, Phase Equilibrium, Reaction Kinetics, Interfacial Phenomena, Electrochemistry, which are the basis for the development of unit operations courses: Unit Operations III and IV and Calculation of Reactors. The objective was to obtain products that would use natural raw materials as much as possible for their formulation. The following products developed in the course are presented:

1. Liqueur by fermentation of sugar cane syrup

1.1 Objective: To produce a creamy liqueur with an alcoholic degree of 40º of three different flavors using the processes of fermentation and distillation to obtain the alcohol.

1.2 Contents:

Conceptual: Solutions, phase equilibrium, chemical equilibrium, reaction kinetics, interfacial phenomena. Other related content: Food science

Procedural: Calculation of colligative properties, determination of reaction rates and suitable operating conditions to obtain higher yields of the product, use of binary and ternary phase diagrams, use of the principles of liquid-vapor equilibrium and distillation for the purification of substances.

1.3 Description of the Procedure: The liquor is made from the fermentation of sugar cane syrup and distillation to obtain high purity ethanol, using brewer's yeast as a fermentation agent, as well as agents such as ammonium sulfate and sodium phosphate to be a suitable medium for the action of yeast. The ethanol produced at 97% (obtained through double distillation) was diluted to 40% (commercial concentration) and then used to produce flavored liquors of chocolate, vanilla and coffee.

2. SPF 50+ Sunscreen

2.1 Objective: To formulate a sunscreen with a sun protection factor SPF greater than 50 that has high stability, appearance and pleasant organoleptic properties.

2.2 Contents:

Conceptual: Solutions, Interfacial Phenomena. Other related contents: Cosmetology, Health sciences.

Procedural: Calculation of colligative properties, use of binary and ternary phase diagrams, use of the principles of physicochemical formulation for the formation of emulsions.

2.3 Description of the procedure: The sunscreen is formulated based on an emulsion of triglyceride oils of vegetable origin (coconut and canola), nonionic ethoxylated and non-ethoxylated sorbitan ester surfactants, chemical sunscreens as active ingredient (Benzophenone, Parsol), preservatives, stabilizers and thickeners. It is obtained through a low energy method.

3. Artisan beer

3.1 Objective: To produce artisan beer based on malted barley and malt extract, which possesses adequate organoleptic properties: color, flavor, aroma.

3.2 Contents:

Conceptual: Solutions, Chemical equilibrium, Reaction kinetics. Other related contents: Food science.

Procedural: Calculation of the composition of the components of a sample, determination of the reaction rates and operating conditions suitable to obtain a higher yield of the product.

3.3 Description of the procedure: Artisan beer is produced through a fermentation process by activating the yeast and preparing the must with the malted barley and the malt extract. The baking is done and the hops are added. The wort is cooled to 35 °C and the yeast is added. The fermentation time is 2 to 3 weeks, an adequate amount of sugar is added and bottled to proceed to the gasification, through the formation of CO2 in 1 or 2 weeks. The reaction kinetics are studied by measuring the concentration of glucose in the system as a function of time.

4. Anesthetic cream based on eugenol

4.1 Objective: To obtain a formulation for the use of eugenol extracted from cloves as a local anesthetic, which has high stability, appearance and pleasant organoleptic properties.

4.2 Contents:

Conceptual: Solutions, Phase Equilibrium, Interfacial Phenomena. Other related contents: Pharmacology, Dentistry, Health Sciences.

Procedural: Calculation of colligative properties, use of binary and ternary phase diagrams, use of the principles of physicochemical formulation for the formation of emulsions.

4.3 Description of the procedure: A base emulsion formed by paraffin oil, non-ethoxylated and non-ethoxylated sorbitan esters of non-ionic surfactants is formulated in which the recommended amount of eugenol is solubilized as an oil phase for application as a topical and oral anesthetic.

Laboratory of Industrial Chemistry

The course Laboratory of Industrial Chemistry is divided into practices of subjects related to each other in that all are organic chemistry processes, including evaluation of properties of petroleum products, soap production, production of pectins, obtaining dispersed systems and evaluation of some of its properties. For this reason the strategy used in the development of RAIS was the creation of companies that were in charge of planning and coordinating the manufacture of the product in the laboratory environment where twenty researchers where available to obtain the products. The products selected in this work are the following:

1. Healing cream, moisturizer and lip balm

1.1 Objectives: Technological use of beeswax to obtain organic synthetic products, non-toxic to humans. Obtain a healing cream, moisturizer and lip balm based on beeswax and extra virgin sesame oil that has adequate wettability and stability.

1.2 Contents:

Conceptual: Natural raw materials, Phase equilibrium, Solutions. Other related contents: Formulation of products for personal care, health sciences.

Procedural: Use of binary phase diagrams, control of the variables of operation: temperature and quantities of the reagents to produce a substance with the required properties, measurement of the viscosity of the creams produced.

1.3 Description of the procedure: The healing cream, moisturizer and lip balm is formulated by heating the beeswax to about 60 °C, then it is added in the appropriate proportion in the sesame oil under agitation and the system is then cooled to form the dispersion of solid particles of beeswax in sesame oil. Creams with a beeswax content of 15 to 30% can be used as a healing and moisturizing agent. Above 30% a solid paste is obtained which is used as a lip protector.

2. Soap based on beeswax

2.1 Objective: To formulate soap from saponification of triglyceride oils of sesame oil and beeswax esters with sodium hydroxide, which has detergency, foamability, consistency, pH and suitable organoleptic properties.

2.2 Contents:

Conceptual: Chemical equilibrium, Phase equilibrium, Interfacial phenomena. Other related contents: Formulation of products for personal care, organic chemistry.

Procedural: Use of binary and ternary phase diagrams, control of the operating variables: temperature and reagent quantities to generate a saponification reaction with a high yield, foamability measurement and stability of solutions with surfactant.

2.3 Description of the procedure: The soap is formulated through the saponification of the mixture of 20-40% of beeswax and sesame oil. Soap is produced by the cold process, which consists in heating the mixture of beeswax and sesame oil to 60 °C until the beeswax melts, adding the sodium hydroxide in an amount calculated with the index of saponification of the mixture of beeswax and oils. The soap produced is then cooled and stored for one month, during which time the cold saponification reaction continues.

Discussion of results

The products presented and developed in each of the courses fulfilled the objective of integrating the greatest amount of programmatic contents to obtain them. The additional contents that could not be part of the formulation of the product were evaluated through other instruments such as short exams and partial evaluations. The objective of the RAIS strategy is that the developed product integrates most of the knowledge and competences of the course, since, as Morin (2002) states, fragmentary knowledge serves no purpose other than technical uses. The methodology, work plan and evaluation method has been described by the authors (Márquez et al., 2016), achieving that competences are developed in all the contents of the course. This strategy motivates the student, developing skills of creativity and innovation, necessary in the professional field of Chemical Engineering and in the training to carry out applied research. In addition, it was observed that the subjects where RAIS is applied present an average increase of 28% of approved students with respect to the courses that develop the contents with master classes, decreasing the number of students dropping out by 17% on average. This is mainly because the RAIS strategy requires continuous monitoring and compliance with the objectives and competences of the course, both by the young person and the teacher (Márquez et al., 2016).

Conclusions

The execution of products through the Reproduction of an Innovation Environment in the Classroom is a teaching-learning strategy that promotes the development of the innovation and entrepreneurial skills necessary for the student's personal and professional development, integrating the objectives, contents and competences of the courses in Chemical Engineering. This integration is achieved through the active participation of the young person, achieving that there is commitment in the fulfillment of the educational objectives of the course. In addition, the RAIS strategy leaves an added value, as is the innovation and obtaining products for the social benefit of the community in which the university is integrated.

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