Revista Romaneasca pentru Educatie Multidimensionala

Romanian Journal for Multidimensional Education

ISSN: 2066 – 7329 (print), ISSN: 2067 – 9270 (electronic)

Covered in: Index Copernicus, Ideas RePeC, EconPapers, Socionet, Ulrich Pro Quest, Cabbel, SSRN, Appreciative Inquiry Commons, Journalseek, Scipio, EBSCO, DOAJ

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Revista Romaneasca pentru Educatie Multidimensionala, 2013, Volume 5, Issue 1, June, pp:123-139

The online version of this article can be found at:

http://revistaromaneasca.ro

Published by:

Lumen Publishing House

On behalf of:

Lumen Research Center in Social and Humanistic Sciences

Experiences of Innovation Teaching in Bioprocess Engineering University Course

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Abstract

The university course of Bioprocess Engineering is designed to introduce the student to the principles of Biochemical Engineering. The students acquire a global understanding of the biochemical processes. A new teaching methodology, very different from that which was common 30 years ago with non-participatory lectures and classes based on taking notes, was established. In this paper these new teaching strategies have been described. Moreover, the results obtained in the interviews realized along the course in order to determine the satisfaction of the students have been showed. The obtained results permit to verify the total integration of the students into the system, participating and proposing numerous activities. Students were satisfied with new teaching methodology developed in the pilot experience and most of them wished to continue using these new strategies. Summing up, we can conclude that the teaching and learning course was successful. In addition, we detected that the knowledge of methods, practical applications and the reality of biotechnology was increased significantly with this methodology.

Keywords: *Bioprocess; engineering; learning methods; student motivation; university; new strategies;*

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1. Introduction

The university course Bioprocess Engineering is designed to introduce the student to the principles of biochemical engineering, and its application to some of the most important operations in the biotechnology industry. In recent years, biochemical engineering has reached a major impact. In this course, the students acquire a global understanding of the biochemical processes (either fermentative or enzymatic). As such, tools such as fundamentals of industrial biotechnology, enzymatic and fermentative process kinetics and the introduction to reactor calculations based on mass balances. From there, concepts about unitary operations directly linked to biochemical processes of the biotechnology industry, such as the sterilization of means and equipment will be studied, as well as airing and stirring in bioreactors. After this part of theoretical fundamentals is over, the focus shifts to fundamentals of increased and decreased scaling and the applications of biochemical processes.

In the last years, the application of new technology to biotechnology courses had been described (Evans, Gibbons, Shah, & Griffin, 2004; Montgomery, 2003; Sessink, Beeftink, Hartog, & Tramper, 2006; Sessink, Van der Schaaf, Beeftink, Hartog, & Tramper, 2007). The rapid development of Internet communication technology has made e-Learning an attractive alternative tool to facilitate learning and increase the student motivation (Bodzin & Cates, 2003). A new teaching methodology, very different from that which was common 30 years ago with non-participatory lectures and classes based on taking notes, was established. A new Bioprocess Engineering course was designed and successfully implemented until today. In this course the teaching strategies and learning systems was lectures, tutorial and practical, in-class discussion, journal reflection, laboratory practice, conceptual maps, collaborative learning, seminar work with oral presentation, field visits, hands-on, web-based learning and assessment tools, service-learning portfolio.

2. Course design

The course Bioprocess Engineering is focused on the interaction of chemical engineering, biochemistry, and microbiology. Cell growth

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kinetics and bioreactor concepts constitute essential knowledge for Bioprocess Engineering students. This subject belongs to the fourth course of Biology degree and it is developed in seven themes in one-semester course. The themes developed during the course are introduction to biotechnology, genetic concepts for microorganisms, kinetic studies, upstream processes, bioreactor design, downstream processes and sterilization. The competences that student should obtain after this course are:

- Develop mathematical models for simulating and understanding biochemical processes.
- Scale-up or scale-down production in bioprocesses.
- Suitably chosen laboratory biotechnology experiments.
- Design of biotechnological processes and optimize existing processes.
- Evaluate the economic feasibility of the production process.
- Recognize the implications of environmental standards and standards for consumer goods, and of the control of their observance.

For this purpose along the course several activities are developed in order to improve the student understanding in the subject. In this course the teaching strategies and learning systems were:

- Lectures. Lectures provide a guide to the subject matter and set out the foundations on which the student can build your knowledge.
- Tutorial and practical. Tutorial and practical give to the student the opportunity to develop themes or discuss problems. These classes are much smaller than lectures, with the tutor providing a key link between student and the course work.

- In-class discussion. Class discussions help students to examine, evaluate and share knowledge about a subject matter. They provide an atmosphere for students to create new ideas, view from different perspectives, and improve their communication and expression skills.

- Journal reflection. Reflective writing assignments allow students to demonstrate their mastery of concepts discussed in class and an opportunity to present questions about the lectures and/or discussion materials.

- Laboratory practice. The objective of the laboratory practice is to introduce students to experimentation, problem solving, data gathering, and scientific interpretation. Students learn many practical aspects of cell culturing include many new procedures for students (e.g., reactor building, medium preparation, sterile sampling, cell counting, etc.) and apply the theory to a practical situation.

- Collaborative learning. Proponents of collaborative learning claim that the active exchange of ideas within small groups not only increases interest among the participants but also promotes critical thinking. There is persuasive evidence that cooperative teams achieve at higher levels of thought and retain information longer than learners who work quietly as individuals. The shared learning gives an opportunity to engage in discussion, take responsibility for their own learning, and thus become critical thinkers.

- Seminar work with oral presentation. During the course students prepared and presented their seminar works in groups and individual.

- Field visits. The visits aim to be interesting and suitable in several themes about the industrial Bioprocess. By showing what actually goes on at a place of work, students will get a much better view of a particular business environment and will achieve a greater awareness of careers and opportunities in a particular subject area. Field visits provide a source of realistic examples to be used in class to practise the standard methods and a potential source of data for

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coursework. Moreover, it provides some stories which may be used to add interest to lessons.

- Hands-on, active participation. Designing activities so that students are actively involved in the project or experiment. Hands-on participation is as important as verbal participation in the activity.

- Web-based learning and assessment tools. Online formative assessment has the added advantage of allowing greater independence and self-direction on the part of the student, thus enabling staff to focus attention on students in greater need of assistance added that online self-assessment allows flexibility with regard to the time and place in which assessment is undertaken, rapid delivery of individualised feedback and opportunity for repetition.

- Service-learning portfolio. This final project documents evidence of the processes utilized and products completed during this service-learning course. The portfolio includes a combination of the following items: a weekly log of service activity, copies of journal reflections, directed writings assigned during the class period, and/or copies of products completed during the service experience (e.g. agency brochure, advocacy letters, round table agenda, etc.). The portfolio also includes a required self-assessment essay that summarized the student's current view of biotechnology including the potential benefits and drawbacks of its development and deployment.

3. Example of seminar work

An activity developed in the course is the use of scientific research articles as a tool to approach students the development of an industrial bioprocesses. For this purpose, collaborative learning, in which scientific research article must be used, was proposed to the students. The students have to prepare and present a seminar based on the research article. The objective of the work was to describe an innovative bioprocess where a bioreactor was used. The work must develop all stages related to a bioprocess (propagation of cultures,

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bioreactor, separation and purification of products and effluents treatment). The steps for carry out this work are represented in Figure 1.

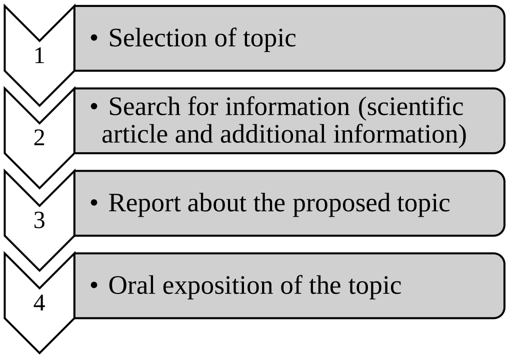

Figure 1.- Steps for developing the seminar work with scientific research articles.

3.1. Activity plan

Along the course several activities related to the seminar work were developed. The activity plan of the proposed work is displayed in Table 1. A detailed description of the activities per week is described below:

- Week 1. During the first week, master classes (2h) were dedicated to explain the stages of a bioprocess.

- Week 2. A seminar (1h) was dedicated to describe the activity and methodology in which the scientific article must be used. In this seminar the deadline dates and way to evaluate the proposed activity, were also indicated. The work was based on cooperative activity. Thus, groups of two people were formed. Topics about different bioprocess were proposed by the teacher in order to help the students. Nevertheless, students could propose alternative topics. At the end of this seminar, the groups let teacher know the selected topic. During this week, the groups began to search for scientific article and additional information about the selected topic (3h). For this activity, the groups mainly used web database as Scopus or Science Finder. Scientific research articles are mostly in English for

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this reason other generic skill as foreign languages are included in this activity.

- Week 3. In this week, the groups continued searching the information necessary to accomplish the proposed work (3h).

- Week 4. During this week, the groups redacted an outline report based on the information (1h). At the end of this week the second seminar was realized (1h). In this seminar, the groups showed the documentation (scientific article and additional information) and the outline report to the teacher. In addition, the groups used this seminar to show all the doubts or problems related to the work. The teacher's function was resolved all doubts and evaluated the documentation and the outline report.

- Week 5. This week was free of class and the groups can begin to develop the written report about the topic (3h).

- Week 6-7. During these two weeks the teacher fixed with each group a mentoring to evaluate the work (1h per group). The groups continued with the written report (6h)

- Week 8. Along this week the groups had to deliver the report. The groups began to prepare their oral presentations (2h).

- Week 9. The teacher sent (email) the comments about the report to the groups. The groups continued with their oral presentation preparation (3h).

- Week 10-17. Along these weeks, seminars in which each group had to present its topic were carried out (1h). The time of each presentation should be 40 minutes and after the presentation each group had to do a question related to the presentation.

In order to evaluate the oral presentation a rubric as appear in Table 2 was used. To get this rubric, a free web tool Rubistar (ALTEC, 2000) was used. The teacher and each group utilized this tool to evaluate the oral presentation.

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Table 1.- Activity plan for seminar work

Week	Activity	Teacher's task	Students' task
1	Master class about the stages of a bioprocess	X	-
2	Seminar 1:		
	- Explanation about the proposed work	X	-
	- Formation of the groups	-	X
	- Proposed topics	X	X
	- Choice of topic	-	X
	Search for scientific research article and additional information	-	X
3	Search for information (continuation)	-	X
4	Write the structure of the report	-	X
	Seminar 2:		
	- Evaluation of scientific article and additional information presented by the group	X	-
	- Group proposal on the structure of work	-	X
	- Doubts about the work	-	X
5	Development of written report about the topic	-	X
6-7	Mentoring with each group to evaluate the work	X	-
	Development of written report about the topic	-	X
8	Delivery report	-	X
	Begin with the preparation of oral presentation	-	X
9	Send report evaluation	X	-
	Preparation of oral presentation	-	X
10	Send comments about the report	X	-
	Preparation of oral presentation	-	X
10-17	Seminar 3-10		
	- Oral presentation of each group	-	X
	- Evaluation of the oral presentation	X	X

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Table 2.- Rubric for seminar work evaluation

	Very Good (4 points)	**Good (3 points)**	**Poor (2 points)**	**Very Poor (1 point)**
Content	Shows a full understanding of the topic.	Shows a good understanding of the topic.	Shows a good understanding of parts of the topic.	Does not seem to understand the topic very well.
Preparedness	Student is completely prepared and has obviously rehearsed.	Student seems pretty prepared but might have needed a couple more rehearsals.	The student is somewhat prepared, but it is clear that rehearsal was lacking.	Student does not seem at all prepared to present.
Time-Limit	Presentation is 40 minutes long.	Presentation is 30 minutes long.	Presentation is 20 minutes long.	Presentation is less than 15 minutes
Speaks Clearly	Speaks clearly and distinctly all (100-95%) the time, and mispronounces no words.	Speaks clearly and distinctly all (100-95%) the time, but mispronounces one word.	Speaks clearly and distinctly most (94-85%) of the time. Mispronounces no more than one word.	Often mumbles or cannot be understood or mispronounces more than one word.
Vocabulary	Uses vocabulary appropriate for the audience. Extends audience vocabulary by defining words that might be new to most of the audience.	Uses vocabulary appropriate for the audience. Includes 1-2 words that might be new to most of the audience, but does not define them.	Uses vocabulary appropriate for the audience. Does not include any vocabulary that might be new to the audience.	Uses several (5 or more) words or phrases that are not understood by the audience.
Props	Student uses several props (could include costume) that show considerable work/creativity and which make the presentation better.	Student uses 1 prop that shows considerable work/creativity and which make the presentation better.	Student uses 1 prop which makes the presentation better.	The student uses no props OR the props chosen detract from the presentation.

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4. Example of planning of field visits

Visits by student groups to process plants have to be adequately planned and integrated in the context of the course. A number of aspects need to be carefully considered (Figure 2), and the course content has to be customized in order to prepare the students and assure optimum learning results. The objectives of the visits have to be clear to all involved parties (i.e. academic and industry staff, students), as well as the relationship between the visited facility and the student task or learning objective.

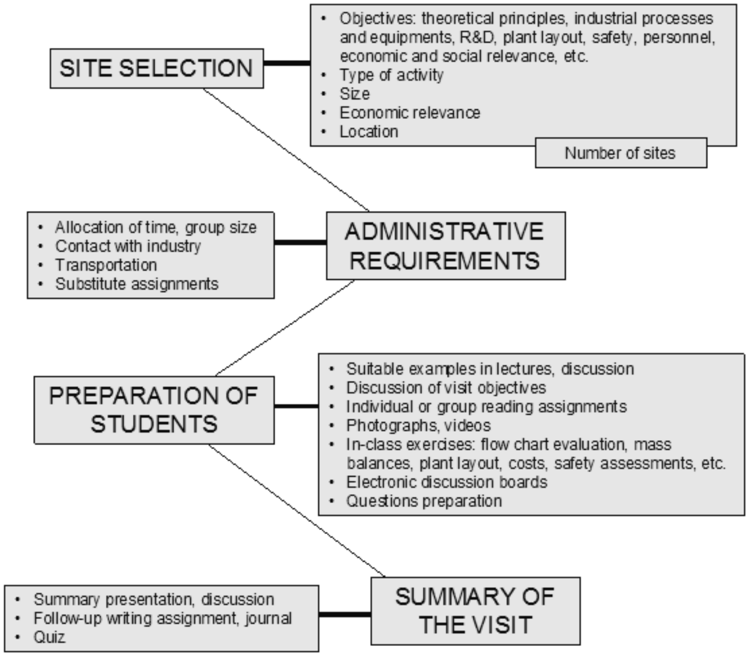

Figure 2.- Main aspects to be considered when planning a field site visit

4.1. Site selection

The effectiveness of a visit to an industrial facility strongly depends on the adequate selection of the site, taking into account the specific course in which it is integrated. This kind of activity should not be considered by the students as a mere excursion or leisure time away

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from school. The specific objectives for the visits should be clearly identified, and therefore it must be decided if the visit will focus on a whole plant or a part of it. Some general objectives to be considered are:

- To demonstrate the application of scientific or technical concepts and principles learned in the classroom.
- To illustrate processes and products manufactured in the biotechnological industry.
- To emphasize the relevance of scientific research in developing industrial processes and products.
- To understand the operation of specific equipment.
- To observe the actual layout of a biotechnological industry plant and how a piping and instrumentation diagram is implemented.
- To understand personnel organization and functions in plant operation.
- To develop awareness of the standards of safety, including risk assessment.
- To understand the commercial, social and economic relevance of the studied industrial sector.

The industries to be visited have to be selected, based on their accordance to the defined learning objectives, but also on criteria such as type of activity, size, economic relevance and location. It would be beneficial to propose visits to more than one industry, in order to allow the students to reflect on the similarities and differences between diverse industrial processes. For instance, in the specific case of the discussed Biotechnological Processes course, visits to food and beverages industries (i.e. beer, wine or cheese manufacture) and pharmaceutical industries are proposed. Two or three days field trips could be an interesting activity, although not always feasible due to economic and time restrictions.

4.2. Administrative requirements

The organizational requirements for implementing field site visits need to be carefully considered. Visits undertaken within the teaching term have implications for timetabling, class management and teaching time utilization, which are more complex as class sizes increase. Also, safety considerations in industry restrict student numbers in the plant at a given time. Planning of the visits should take into account:

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- Allocation of time for the visit. The type of industry and the objectives of the visit have to be considered. Mid-term is usually recommended for this kind of activity, in order to allow the student to get a basic knowledge on biotechnological processes prior to the visit; also, at the end of the academic year the students become preoccupied with vacations and examinations, and the visits are less effective. Additionally, the other teachers have to be informed in advance of the planned activity, especially if their courses could be affected.

- Contact with industry. The companies have to be contacted, in order to get the authorization for the visit. The date, itinerary, group size and other requirements (i.e. safety, legal) should be clearly specified in advance. It is also important to know if a guide will be provided by the company, and to discuss the visit with the guide beforehand, if possible. Permission to photograph during the tour could also been asked for, since the pictures can be used in the post-tour discussion.

- Transportation. This aspect should be carefully organized, in order to avoid delays and misunderstandings. The time and meeting point, as well as the identification of the transport, has to be clearly specified to the students, both on the way out and the return trip.

Additionally, the lecturer has to foresee the possibility of some student having unavoidable conflict, such as illness or a family emergency, which could prevent attendance to one or more of the site visits. As a general rule, the students should attend at least to one of the visits to receive at least part of the benefit of the external interaction provided by this activity. However, a substitute assignment has to be given to the students who are unable to attend one of the visits.

4.3. Preparation of the students

The course content has to be customized in order to adequately prepare the students to the visit. Lectures should include examples from the companies and industries to be visited whenever possible, and allow

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time for discussion. The objectives of the field trip should be discussed with the students prior to the activity.

Students are given individual or group reading assignments, such as background materials which are either provided by the company or prepared by the lecturer. Utilization of plant photographs or videos is recommended, and in-class exercises are designed for each visit, including aspects such as flow diagram evaluation, mass balances, plant layout development, estimation of operating costs, safety assessments, etc.Also, electronic discussion boards are a useful teaching tool: suitable discussion subjects are posted by the teacher, in order to promote the online exchange of information and opinions between the students. Sustainability and safety issues are usually successful discussion topics. It is especially interesting that the students prepare a number of questions to be posed during the visit, which will be also posted in the electronic discussion board, in order to avoid duplication.

4.4. Final summary of the visit

After each visit, a summary should be presented in the classroom, in which both lecturer and students participate. A follow-up writing assignment is proposed, in the form of a journal where the students reflect on the experience. Additional questions could arise at this stage, which can be answered by the lecturer or proposed as group assignment to the students for further discussion.

Also, a quiz over specific aspects of the visit could provide useful feedback for future activities, and act as a motivating instrument. The results of the quiz were found to be very satisfactory, with marks higher than 75% in more than 80% of the students.

5. Student perception

Experiences from the previous academic years and some interviews similar that showed in Table 3, demonstrated that students have positive attitude toward using computer technology and prefer the new teaching-learning methodology than traditional.

Students were satisfied with new teaching methodology developed in the pilot experience and most of them wished to continue using the e-learning support (Figure 3). The anticipated difficulties were few and the results are better than expected. Students accepted the combination of

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classroom and e-learning environment positively and the chosen e-learning environment proved to be successful.

Table 3.- Sample items of student perception

Items	SA	A	U	DA	SD
Teaching strategy improve the performances of the students?	1	2	3	4	5
Meet the expectations raised at the beginning of the course	1	2	3	4	5
Have you obtained the proposed knowledge?	1	2	3	4	5
Have you gain the proposed competences?	1	2	3	4	5
Have you acquired the proposed general skills?	1	2	3	4	5
It has motivated you to work over the course	1	2	3	4	5
You felt more involved in the course	1	2	3	4	5
Prefer this new methodology to traditional	1	2	3	4	5
Helped you relate this subject with other subject of the career	1	2	3	4	5
Offered a more efficient way to understand the concepts	1	2	3	4	5
Helped you understand your grade status in class	1	2	3	4	5
Helped you to know your evolution along the course	1	2	3	4	5
Higher interaction teacher-student	1	2	3	4	5
Stimulated your team work	1	2	3	4	5
The student work demanded made you more interested in the course content	1	2	3	4	5
Was useful the seminar work with oral presentation?	1	2	3	4	5
Journal reflection allowed you to demonstrate your mastery of concepts discussed in class	1	2	3	4	5
Do you improve your ability to look for information?	1	2	3	4	5
Are you in accordance with the assessment tools?	1	2	3	4	5
With field visits you feel more connected to the particular business environment	1	2	3	4	5
Do you like computer technology?	1	2	3	4	5
It possible to adjust place, speed and way of learning according to your needs and capabilities.	1	2	3	4	5
Does it improve your ability to explain and defend your work?	1	2	3	4	5
Do you like computer technology?	1	2	3	4	5
The new system, changed your studied way	1	2	3	4	5
Are you in accordance to the temporal distribution of the course?	1	2	3	4	5

SA, strongly agree; A, agree; U, undecided; D, disagree; SD, strongly disagree

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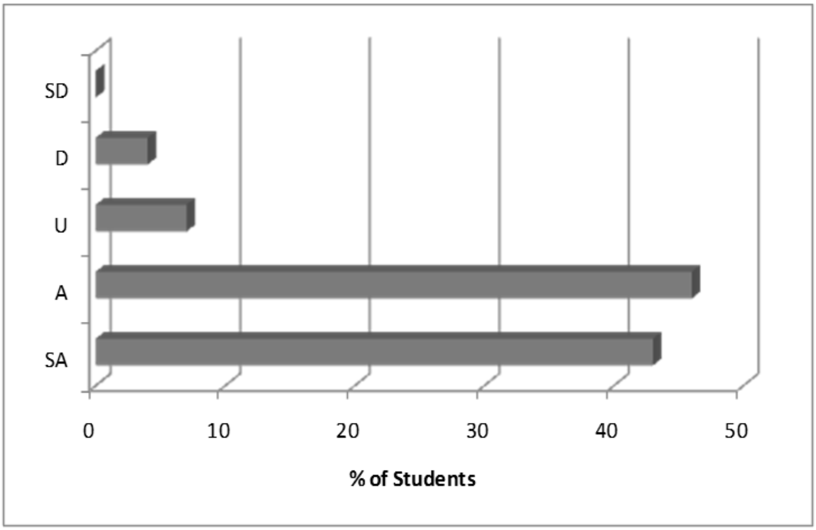
Figure 3.- Student´s satisfaction with Bioprocess Engineering project



Our experience allows us to conclude that by using of this methodology it is possible to achieve the following goals:

- Enable students a uniform access to all teaching material
- Direct students toward other learning resources on the internet.
- Improve and accelerate communication between students and teachers.
- Improve and accelerate communication among students.
- Stimulate students' team work.
- Enable students to adjust place, speed and way of learning according to their needs and capabilities.
- Provide students with self-evaluation mechanism.
- Facilitate teachers monitoring students' progress.
- Simplify and speed up the procedure notifying students.
- Track student's response, their initiative, suggestions and needs.
- Automate monitoring system of student progress.

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6. Conclusions

The obtained results permit to verify the total integration of the students into the new system, participating and proposing numerous activities. Specifically the seminary work was satisfactorily developed for each group. Although initially there were some troubles with the students with regard to use scientific articles written in nonnative language, the results obtained after the seminars were very positive. The use of scientific research articles was shown as a new tool to increase the knowledge about the initial stages of industrial and new bioprocesses in development.

Regarding to field visits the students generally agreed that the visits were necessary, interesting and enjoyable, and that they added to their knowledge on biotechnological processes. The classroom activities prior to the visit were considered useful, and collaborative tools were preferred (i.e. electronic discussion boards and classroom discussion). The selected industries were considered adequate, although more attention on the pharmaceutical and environmental sector was proposed.

Students were satisfied with new teaching methodology developed in the pilot experience and most of them wished to continue using these new strategies. Summing up, we can conclude that the teaching and learning course was successful. In addition, we detected that the knowledge of methods, practical applications and the reality of biotechnology was increased significantly with this methodology.

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