

Continuous Innovation Model for an Introductory Course to Industrial Engineering

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Abstract

The Industrial Engineering Department at the University of Chile has been a national leader in teaching innovation, having gradually evolved from an educational paradigm based on acquiring knowledge to one that focuses on the development of attitudes and skills. As a result of this evolution, the course Introduction to Industrial Engineering was created in the mid-1990s, based upon a radical constructivist approach. The main goal of the course is to expand each student's self- and social- awareness, increasing their capacity to design and manage their educational process. This paper presents basic elements of this course and its main results, and proposes a model for continuous evaluation and improvement based on the active participation of current and past students. Additionally, the paper provides new evidence of the benefits of a constructivist approach to educational innovation.

Introduction

The Introduction to Industrial Engineering (IN 31A) course is the main entrance to the specialization in Industrial Engineering and to the Department of Industrial Engineering (DII) as the new academic home for students who have completed five semesters of the common core¹ in the Engineering School of the University of Chile.

The main objectives of this course are to:

- Expand self-awareness and emotional intelligence
- Expand awareness of the paradigm shift the world is going through
- Get to know the Department of Industrial Engineering as an academic center
- Increase entrepreneurial thinking, teamwork, and innovation capacities

Based on these specific objectives, the central focus of the course is to:

- Increase students' consciousness of their roles as designers and managers of the learning and transformational experience they are beginning in DII
- Stimulate their ambition, personal empowerment, and sense of responsibility

The genesis of this course traces back to 1986 when Humberto Maturana, the famous Chilean biologist (National Prize of Sciences in 1994), taught his course Biology of Cognition for Master's students of DII for the first time. A group of full-time professors attended that course and a few of them, including the first author of this paper, experienced a turning point in their thinking about learning. Maturana's radical constructivist argument was that, from a biological standpoint, human beings can never know how things really are and therefore there is neither objective reality nor objective science. This generated a significant debate and important changes in the ways of understanding education, teaching, and learning within the department. It was as a result of that lingering, ongoing debate that the Introduction to Industrial Engineering Course was born ten years later in 1996.

This paper presents the course, its philosophical and pedagogical foundations, and a recently developed methodology oriented towards involving current and past students in the process of assessing and improving the course, which

¹ The Engineering Common Core has included, until now, almost only math, physics, and other scientific courses. Starting year 2007, introductory courses to engineering will be added to this curricular plan.

we refer to as the Continuous Innovation Model (CIM). The main objective of this paper is to add evidence to support the notion that the Radical Constructivism Approach (RCA) opens many possibilities relative to designing, running, assessing, and improving courses centered on the development of skills.

Contextual and Conceptual Framework: Hard Facts of Reality and the Urgent Need for New Paradigms

It is evident that we live an era of radical transformations. Quoting Peter Drucker, we have crossed a “divide” and entered into “New Realities” (Drucker, 1995).

Globalization; the vertiginous, constant, and unpredictable change; and the “technological convergence that has flattened the world” according to Thomas Friedman (2005), create a context which requires us to rethink everything, including rethinking thinking (*The Economist*, 1999). It is not surprising that innovation has been transformed into the number one factor for company success since the end of twentieth century. More important, continuous innovation is no longer enough and radical innovations are necessary in many areas. As Gary Hamel (1996) put it in his provocative article “Strategy as Revolution,” “Let’s admit it. We have reached the limits of incrementalism.”

One of the domains in which we urgently need radical innovation is education. We need to rethink education from its roots, at all levels, and in all domains. Education is always based on philosophical premises: ontological, epistemological, and ethical. There is no way of rethinking and redesigning education if we do not review philosophical assumptions **to become aware of the premises on which education is based and become conscious of their consequences** (Pappas, 2004).

This is not at all an esoteric argument, as some academics still argue. Even the great Peter Drucker indirectly invites us to follow this path when arguing that the most crucial management today is “Managing Oneself” (1999). It should be enough to convince skeptics about the urgent need to review our basic “mental models,” the evolution experienced and promoted by *Harvard Business Review*. The journal broke new ground in December 2001 with the publishing of a special issue entitled “Breakthrough Leadership: Why the Best Strategy Today is Knowing Yourself.” It is important to realize that this was the first special issue of this prestigious and influential journal in its seventy-nine years of existence. The special issue did not focus on marketing, finance, strategy, sales, production, operations management, technology, quality, service or other main management topics. Rather, it drew attention to the human side of management. The following sentence, extracted from the editor’s letter is particularly revealing of this crucial shift in management:

The term “breakthrough leadership,” as we define it, is multivalent—it points in several directions at once. Certainly, it involves breaking through old habits of thinking to uncover fresh solutions to perennial problems. It also means breaking through the interpersonal barriers that we all erect against genuine human contact. (*Harvard Business Review*, 2001)

It is not just a question of including entrepreneurship courses in the curriculum or creating entrepreneurship centers in universities. These are obviously needed but are not sufficient unless they include profound reflection on the “humanologic” foundations of innovation (Schramm, 2006).

It is here that constructivism comes into play. We propose that this particular way of understanding “knowing” and “being” is of great help when dealing with the burning demands for innovation in innovation, derived from changes in the world in which we live. It was on constructivist premises that the Introduction to Industrial Engineering course, and several other courses and training programs, were designed.²

The main distinctive principles of our particular constructivist approach are:

² For an extended presentation of one of the programs most radically designed from radical constructivists premises see: Vignolo *et al*, “Forming Innovative Leaders: the Leadership Skills Certificate program of the Bío Bío Region, Chile,” *Proceedings of the NCIIA 9th Annual Meeting, 2004*.

1. Education is understood, literally, as a process of “construction” and permanent “reconstruction” of the person. Supported by new approaches in neuroscience, our understanding has been evolving gradually towards an interpretation of learning as a biological transformation of the learner, in the interaction and coexistence with the human community in which she/he lives, grows and develops.
2. Knowing is understood, also literally, as a process of “construction” of reality, in which the learner participates actively involving her/his particular paradigms, emotions, and interests, which are all subject of observation, design, and transformation.
3. Learning involves transformations of very diverse nature in the person who learns, the cognitive dimension (knowledge acquisition) becoming less important every day in comparison to the acquisition of values, attitudes, abilities and, mainly, the increase in the levels of consciousness and “contact,” with her/himself and with others.³

The Introduction to Industrial Engineering Course

Based on these principles, the Introduction to Industrial Engineering course has been structured according to the following basic design directions:

1. Students are invited to assume from the beginning of the course, and with increasing autonomy, the role of designer and manager of their personal programs of learning.
2. Emphasis is placed on awareness and development of active listening capacity. This process is introduced and illustrated through different individual and group exercises, as the main factor in the process of “inventing the course” and making it effective, efficient, and pleasant.
3. Emphasis is also placed on increasing awareness and competencies related to entrepreneurship, demonstrating that the course is also an enterprise that the students must guide to a successful end.
4. Moods and emotions are subjects of almost obsessive attention and transformation attempts.
5. The relationship between learning and unlearning is presented and the challenges and pain involved in the process of unlearning what has been previously learned (especially when it was a recent and difficult learning) are exposed and experienced by the students.
6. Great importance is given to learning from peers, with teamwork as one of the most crucial elements of the course.
7. Almost no evaluation of cognitive content of the course is considered. Evaluation is based primarily on performance on the practices, development of the projects, peer evaluation, and self-evaluation.
8. Discussion of theories, methodologies, cases, and other explicit knowledge are always referred to as one of many possible interpretations for the different phenomena under analysis.
9. The pedagogical context is always referred to as a “gymnasium”—mainly in the linguistic and emotional domain—rather than that of “the stage of the sage.”⁴ The professors, instead of lecturing, behave as trainers and facilitators.
10. Learning aimed at increasing awareness of the “real” world is carried out through real projects.
11. Recurrent practices are installed and used as the main method to develop and reinforce skills.
12. Participation of the academic community of DII (senior professors and other authority figures) is fostered. Since 2006 the course has been declared an “institutional course.”

The main activities of this course are:

- a) Lectures The main goal of the lectures (two each week) is to fight indifference and stimulate passion in the students. The professor exposes the cognitive and motivational basis needed for the development of skills and the learning process in general, emphasizing the importance of these in the profession,

3 “Contact” understood in the sense suggested by the Editor in *Harvard Business Review* (HBR). December 2001—Special Issue. Volume 79, Number 11, Letter from the Editor.

4 Pasztor, Ana. “Radical Constructivism has been viable: On Math Education and more.” Commentary presented in *Karl Jasper’s Forum*, October 2004.

- companies, projects, and society. In addition, faculty and young professionals are invited to talk about their research, work, and life experience.
- b) Real projects Students are assigned randomly to groups of six people each. The groups can choose two options:
 - i. “Co-educational projects” with micro-entrepreneurs from poor surroundings of Santiago (Chile’s Capital City). The name of this project is “Building up My Dreams Program” (CMS in Spanish). Students have to train micro-entrepreneurs in management concepts and at the same time they learn about their entrepreneur’s experience under difficult conditions.
 - ii. “Free Enterprise Projects”: Students focus in conceiving and implementing an intuitive business idea, preparing a simplified business plan.
 - c) Mood Setting Practices
 - i. “Tuning in”: Practiced at the beginning of the lecture, students are invited to indicate their moods, interests, questions, and worries upon arrival (see Appendix A).
 - ii. “What did I learn?”: Weekly practice in which students must write an essay about their insights and learning.
 - d) Workshops Two events are added each semester: Induction Workshop and Business Game Workshop. The first consists of a guided visit to the installations and personnel of the department and a formal reception from department authorities. The second, normally run during weekends, is aimed at showing the power of games as learning tools when attitudes and skills are involved.

Some Results

Over the ten years the course has been offered, marks in the Official Educational Survey Report have been above average, notwithstanding the fact that the formal survey does not capture the course objectives adequately (see Appendix B). By far the main benefit of the course has been an increase in students’ willingness and ability to successfully initiate and conduct a wide variety of ambitious and relevant projects. Among them:

- a) The reactivation and empowerment of the Industrial Engineering Student Union;
- b) The creation of DesPerTAR Social (From the Spanish: Desarrollo Personal con Trabajo Aplicado a la Realidad), a students organization oriented to promote “learning in social action”(see www.despertar.cl);
- c) The “Building Up My Dreams” program which was later included in the program of the course; and
- d) Entrepreneurs’ Club, oriented to the development of entrepreneurial spirit, and the generation of start-ups of students from the entire university(see <http://www.clubdeemprendedores.cl>).

The Continuous Innovation Model

One of the most common problems with courses focused on skills and attitudes, including entrepreneurship, team work, leadership, communications, and negotiations, is the evaluation of its real benefits for students.

While cognitive courses are easily evaluated through traditional tests, attitudes and skills courses are extremely difficult to evaluate. Since evaluation is complex and rarely conducted, innovation faces a great obstacle: changes can be made based on conceptual redesign but not grounded in hard facts.

We propose that a constructivist approach also helps with the challenge of evaluating and improving courses. Based on previous developments in the Management Skills Program (mainly executive programs) (Vignolo *et al*, 2004) a conceptual framework has recently been developed, which we named the Continuous Innovation Model (CIM). The first application of this model to the Introduction to Industrial Engineering course has been running since March 2006. In what follows we present the main elements of this model and the preliminary results.

The main conceptual and operational components of the CIM are:

- a) Conceptual

- In a Radical Constructivist Approach, as previously argued, a course is always built up by the student, based on his/her paradigms, emotions, and interests. That being so, the main actor in the process of evaluating and improving a course has to be the student. That process is continuous: the student constructs, assesses, and reconstructs the course minute to minute, class to class, and week to week.
 - In order to continuously improve the course for each individual student, his/her level of consciousness, mood, and focus of attention is central. Helping students to keep a continuous connection with focus and moods is a crucial part of the CIM.
 - Following the RCA, the teaching team also constructs and reconstructs the course continuously, based on personal moods and reflexion, narratives, and evolving interests, “breakdowns,” and preoccupations generated from the interaction with students and other members of the teaching team.
 - Finally, in a RCA, past students continue to stay involved with the course forever, through a continuously evolving narrative and evaluation of the course. They are each changed by the course and also change their narrative and emotions about the course over time anytime they think about the course. This is especially true when the reconnection with the course is generated by significant breakdowns that trigger deep insights and reflections about the course and its impacts on his/her drift as a professional and as a person.
- b) Operational Taking these conceptual considerations into account the following activities and processes have been designed and implemented at a pilot level:
- “Stretching” At the end of each session students are requested to observe themselves and report their moods, new possibilities that arose for them from the ending session, the degree of expectancies fulfillment, and the general balance of its impact. This form is processed weekly, reviewed, and talked about among members of the teaching team. More than searching for conscious and deliberative redesigns, this activity is aimed at the unconscious transformation of the teaching staff triggered by their participation. Also, deliberate innovations are from time to time generated and implemented this way. The participation of selected students in the review of the weekly report will be added in next stages of the experiment (see Appendix C).
 - Continuous contact with past students. This activity is based on three main considerations:
 - i. Evaluation of a course centered on skills and attitudes requires a long-term perspective. Both near-term and longitudinal follow up with past students in the drift of their careers and lives constitutes a great contribution to this complex task.
 - ii. Past students, both the ones already in the process of transforming in their interaction with the external world (from the university campus) and those still living the transformational process mainly within the campus, have a privileged access to the changes of the contexts in which the students of the course will have to live after the course is finished. Therefore, they can provide great insights about how the course should be improved.
 - iii. Getting in contact with former students opens the possibility of participating in the permanent reconstruction of the course that previous students have, eventually transforming it in a profitable lifelong course.

To benefit from these possibilities, the following activities have been designed and partially implemented:

- a) A first email contact with past students (see Appendix D) aimed at:
- Obtaining current past students’ evaluation of the benefits derived from the different activities of the course;
 - Exploring and increasing their willingness to collaborate in the improvement of future versions of the course and to be contacted for that purpose; and
 - Reinforcing their narratives and reflections—through the distinctions used in the enquiry—about the main topics the course emphasizes.

- b) A second email contact to thank those who answered, containing educational gifts such as a “must-read” new paper or article related to the main topics of the course, a newly developed practice, a video clip and a web page link; and a second enquiry, this time focusing on suggestions to improve the course.⁵

The Main Results of the CIM

The application of the activities already realized has so far produced the following main results:

- An unusually high response rate (according to the Chilean standard) of 30% to the inquiries sent to 1,000 past students (see Appendix E).
- A very promising 75% positive response to the invitation to participate in the continuous innovation process.
- Nearly 50% of former students rated the course impact as high or very high in response to the “Your general evaluation of the impact of the course in your formation as an industrial engineer.” (The scale includes: Very Low, Low, Regular, High and Very High. See Appendix E.)

Conclusions

All the results obtained so far from both the course and the Continuous Innovation Model—still in its infancy—provide strong evidence of the great potential value of a Radical Constructivist Approach to the design, assessment, and continuous improvement of courses centered on the development of attitudes and skills, and the expansion of self awareness.

The Introduction to Industrial Engineering course has made a significant contribution to the empowerment for work of the majority of its students and it has had a crucial impact on a group of them. They have designed and lead, while still students, the implementation of a few very transcendental projects within the Department of Industrial Engineering and the Faculty of Physical and Mathematical Sciences, including the “Building Up My Dreams” program, the annual “World Class Congress,” the “Entrepreneurs’ Club,” the “Social Awareness Initiative,” and the recently launched “Center for Innovation on Teaching and Learning.”

The first results from the CIM inspire optimism regarding the possibilities of relying heavily on past students to transform this and other courses into lifelong experiences of continuous learning.

We believe that this approach can be of great help for any sort of courses, in particular for those focused on skills and attitudes. We recommend some theoretical groundwork on constructivism prior to the use of models of this kind. It is also necessary to understand that students’ resistance to this sort of learning experience is different and more complex than to that of traditional courses.

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⁵ This step has not yet implemented to date of submitting the paper.

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The Economist, December 18th, 1999, p.63

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Appendix A

TUNING IN

Name:

Date:

Time of Arrival:

1. Which are your moods (or emotions) at the beginning of this session? Select three from the following list or add other distinctions

___ Enthusiasm

___ Interest

___ Confusion

___ Acceptance

___ Peace

___ Restlessness

___ Ambition

___ Resentment

___ Gratitude

___ Expectation

___ Skepticism

___ Confidence

___ Apathy

___ Anger

___ Indifference

___ Tranquility

___ Impatience

___ Curiosity

___ Preoccupation

___ Prudence

___ Hope

___ Happiness

___ Anxiety

___ Euphoria

___ Resignation

___ Distrust

OTHERS: _____

2. Which are your obstacles, breaks, worries at the beginning of this session that, in your opinion, can affect you to take advantage of it?

3. What would you like to happen today? (What interests or questions would you like to see considered in this session?)

Appendix B

Official Educational Survey Report (2001-2005)

	Introductory Course to Industrial Engineering	Average
Fall 2001	5.7	5.9
Spring 2001	5.8	5.5
Fall 2002	5.7	5.8
Spring 2002	6.4	5.8
Fall 2003	6.3	5.7
Spring 2003	6.4	5.8
Fall 2004	6.7	6.0
Spring 2004	5.5	5.7
Fall 2005	6.6	5.9
Spring 2005	6.2	6.0

The Grading System is from 1.0 to 7.0

Appendix C

STRETCHING Name: _____

Date: _____

1. Which are your moods (or emotions) at the end of this session?

Mark the three options that most accommodate you

___ Enthusiasm

___ Interest

___ Confusion

___ Acceptance

___ Peace

___ Restlessness

___ Ambition

___ Gratitude

___ Expectation

___ Resentment

___ Skepticism

___ Confidence

___ Apathy

___ Anger

___ Indifference

___ Tranquility

___ Impatience

___ Curiosity

___ Preoccupation

___ Prudence

___ Hope

___ Happiness

___ Anxiety

___ Euphoria

___ Resignation

___ Distrust

OTHERS: _____

2. What new possibilities do you see for yourself triggered from this session?

3. What questions are you leaving with? Which subjects did not remain clear or left you confused?

4. In a phrase: how would you rate this session? Give it a mark from 1.0 to 7.0

5. How would you rate yourself as a responsible constructor of your learning process in this session?

Appendix D

Dear Student,

Our eagerness to improve the formation process of the Industrial Engineers had made us invite our students and former students to collaborate, comment, and propose changes to the curricular plans and the course contents.

In this opportunity we would like you to answer the survey "Improving the Industrial Engineering Career," which refers specifically to the Introduction to Industrial Engineering course. It will take you five to ten minutes.

We appreciate your collaboration.

Kindly,

Máximo Bosch
Undergraduate Program Chief
Department of Industrial Engineering
University of Chile

Appendix E

Improving the Industrial Engineering Career

Dear ICI:

The trend in the world's best universities is to improve in a continuous way their study plans and programs through a constant feedback with their former students. In our department we are working on this line, through a pilot program with the course "Introduction to Industrial Engineering." We invite you to answer the following survey.

1. Your spontaneous memory of the course, in a phrase is: (What comes automatically to your mind when you think about the course?)
2. The year and the term in which you made the course was:
3. Your current evaluation of the benefit given by the course, in the following scopes is:

Scope	Very Low	Low	Regular	High	Very High	Without Notion
Acquired Knowledge: - Relevant theories - Relevant information - Relevant techniques						
Behavioral Changes						
Mood improvements						
Manager Skills Development	Listening					
	Learning to learn					
	Team working					
	Communication					
	Leadership					
Emotional Intelligence	Self awareness					
	Self management					
	World awareness					
	Relations management					
Innovation capacity						

Network management							
Others							

4. Your general evaluation of the impact of the course in your formation as an industrial engineer:

Very Low	Low	Regular	High	Very High	Without notion

Optional Comment:

5. Your evaluation, in terms of learning and integral formation, of the different activities is:

Activity	Very Low	Low	Regular	High	Very High	Without notion
Lectures						
Listening to Professionals						
Sessions of Investigation Methodologies						
Group Project						
Building My Dreams						
Readings						
Induction day						
Workshop: Learning to learn / Business game						
What did I learn?						
Tuning In and Stretching						
Exam: Learning Essay						

6. My interest and disposition to collaborate with the continuous improvement of this course is:

Very Low	Low	Regular	High	Very High

7. I authorize you to contact me again: Yes____ No____

If your answer was yes, please give us your current contacts:

Email: _____

Telephone: _____