DEVELOPING TOOLS FOR THE EVALUATION OF KNOWLEDGE BUILDING IN INDUSTRIAL ROBOTICS STUDENTS

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ABSTRACT

Developing tools is presented to evaluate the experiencing of knowledge-building processes in simulation environments of manipulator robots by students in a course on Foundations of Industrial Robotics (FIR) in engineering, starting from the design and implementation of a graphic simulation setting of real robotized manipulators at the Departamento de Ingeniería Eléctrica of the Universidad de Santiago de Chile (DIE-UdeSantiago). In general, in this work inductive learning and learning through guided discovery by the students is given preference, ensuring the design and experiencing of a set of didactic situations that allow the students to build their own knowledge. That is why cognitive theories of teaching and learning are considered, requiring –by the student– greater activity of an intellectual character and sharpening their sensory characteristics. Within this context, the errors made during this learning process are seen as an important factor in the knowledge-building process, because making mistakes invites the students to become motivated and to try different solution alternatives. Therefore, some of the learning situations that should be evaluated are the following:

- Integration of different areas of knowledge, since robotics is a multidisciplinary science.
- Operations with manipulable objects, favoring going from abstract to concrete.
- Appropriation of graphic language as if it were mathematical language.
- Operation and control of different variables in a synchronic manner.
- Development of systemic thought.
- Building and testing the students' own knowledge acquisition strategies through pedagogical orientation.

The settings in which the design and implementation of a graphic simulation environment of real robotized manipulators allow the students to build knowledge (innovation to be implemented) will be evaluated, are presented. These environments are related preferentially with teaching and learning processes. The specific aspects to be evaluated, which are derived from the definition of the impact dimensions or sub-dimensions are pointed out. The kinds of study, approach, design, stages, participants and procedures to be used to evaluate the impact of the innovation that will be implemented are described. The techniques and instruments for measuring the impact level of that innovation are adapted and specified. The main results that the students are expected to achieve after taking a course on FIR are described, and the conclusions of this work are given.

KEYWORDS

Integrated Learning Experiences, Conceive, Design, Implement, Design-Build Experience, Standards: 5, 8

1. INTRODUCTION

Quality in higher education is conceived as perfection or consistency, ability to fulfill the mission, added value, transformation, as well as complying with standards or requirements, or as a comparative point of reference (Altbach, Ph. G. 1986; Casaliz, P. 1991; Espinoza, González, Poblete, Ramírez, Silva and Zúñiga, 1994; Dias Sobrinho, J. 2006). In view of this diversity, some authors point out that the concept of quality fits the interests of the involved actors or that it can only be managed as a function of certain dimensions or action settings associated with some values points of reference. In short, it can be pointed out that the concept of quality must be linked with a dynamic and changing educational project (García de Fanelli, A. 2001; Espinoza, O. & González, L. E. 2006; Zúñiga, M. 2007; Backhouse, R; Grünewald, I.; Letelier, M., *et al*. 2007). Given this scheme, improvement and quality assurance in higher education can be associated with different functions such as evaluation, superintendence, information, and certification. These functions appear in the different development stages of universities, which go from submitting the foundation project to their fully autonomous operation. Institutions that look after quality in a wide sense must always have a critical and reflexive view of their everyday activity that is permanently compared with their ideas and their values principles. This new conceptualization of the notion of quality in higher education, more dynamic and associated with institutional management, leads to the application of more sophisticated evaluation models, going from linear schemes to matrix approaches, and more recently, to systemic references such as the Total Quality Management (TQM) model and the European Foundation for Quality Management (EFQM), both addressed rather to the evaluation of institutions (Sirvanci, M. 2004). In this educational modality the concept of quality has different scopes, depending on the field of action in which it is applied, since it is possible to visualize different conceptualizations associated with evaluation, management and strategic planning processes, among others. That is why the requirement of having a better university education is currently demanded by society, an imperative of the demanding world in which we are immersed, which has created the urgent need for the work of mankind to be much more efficient, and this requires better theoretical-practical training. It is in this context that universities play an extremely important role in the formation of human resources of the highest level and in the creation, development, transfer, and adaptation of technology in such a way that what they do to respond adequately to the requirements of modern society becomes a strategic imperative for national development. However, one of the most serious criticisms that can be made with respect to the matter of teaching quality refers to the lack of sufficiently developed and validated theories and models that explain the way in which different elements or variables, like those identified in this work of reflection on the present situation of university teaching, have an incidence on, affect or alter the quality of teaching in higher education, and how productivity is evidenced in this process. From some systemic views that are translated into evaluation and management models of quality in higher education, such as those mentioned in the above reflections, and considering how the new Information and Communication Technologies (ICT) have evolved spectacularly in recent years, especially thanks to their interconnection capacity throughout the network, the field of particular interest of this work is centered on educational robotics.

The ICT, which constitute a new development stage in the educational field, are having a positive impact on the organization of teaching and on the learning process. The adaptation of the educational environment to this new potential and its adequate didactic use represent an unprecedented challenge. In this respect, robotics can be considered as one of the already mentioned new technologies that can be presented and utilized in many different ways in the teaching-learning processes, and that is why educational robotics is a current research topic at the international level, because it is a multidisciplinary area of engineering that has been an invaluable element for promoting science and technology as something amusing (Acuña, A. 2004; Perkins, D. 2006; Parker, L. E. 2008). However, the high costs of its implementation as well as the difficulty in training instructors have made it increasingly common only in first world countries where higher budgets are available for its diffusion (Ortiz, J. G., Bustos, R., & Ríos, A. 2011; Comité Español de Automática (CEA) 2012). In common with every digital technology, its incorporation into the formal educational system requires a different vision of the teaching-learning process (Ortiz, J. G. 2011; Alimisis, D. 2012). The role of teachers and students, the way of organizing the lecture room, the time and space for the activities, the methodology, etc., are some of the variables that can be analyzed in the search for knowledge that can lead to improving the use of robots at the educational level (DIDE 2004; Petrovic, P. 2012). That is why sharing the results of experiences and research, either face-to-face or virtual, is a key factor to advance in this process.

From a Vygotskian perspective, educational robotics can be understood as a medium for doing, understanding and learning reality. It is a field of action whose purpose is the generation of learning environments based essentially on student activity. One of its most interesting factors is that the integration of different areas occurs naturally. In this innovative learning environment the students occupy most of their time simulating phenomena and mechanisms, designing and building prototypes that are micro-representations of the surrounding technological reality, or their own inventions. But which are the benefits of educational robotics? It generates interesting and motivating learning environments where the teacher becomes a facilitator and the students become active managers, promoting curricular transverseness, where different knowledge come together to solve the problem at hand, in addition to allowing the establishment of relations and representations.

Educational robots have a very simple control compared to the structure of industrial robots, because they have a microcomputer or microcontroller in a very small space, commonly called the "robot's brain" in analogy with the human brain. However, nowadays we need to advance in the knowledge and applicability of industrial robots that are present in highly transverse contexts and situations (Ortiz, J. G. 2011; Alimisis, D. 2012; Urrea, C., & Kern, J. 2011a; Urrea, C., & Kern, J. 2011b; Urrea, C., *et al*. 2011c; Urrea, C., & Kern, J. 2011d; Urrea, C., *et al.* 2012a; Urrea, C., & Kern, J. 2011b; Urrea, C., & Muñoz, J. 2013; Urrea, C., & Kern, J. 2013; Urrea, C., & Kern, J. 2014). That is why this work is centered on the evaluation of knowledge building made in educational robotics as a means for learning in which the main motivation is the design and construction of its own creations, which take place first mentally and later physically, where the design and implementation of simulation modules of robotized systems of an industrial kind is proposed, that will allow gaining experience from knowledge building. This will allow the students in the last year of the career of Electrical Engineering of the DIE-UdeSantiago, specifically students taking a course of Foundations of Industrial Robotics, to acquire tools that will allow them to represent graphically, but very close to reality, and safely, the dynamic behavior of robotized manipulators which under direct operating conditions (working with real robots) can even result in accidents of workers in industrial environments (students in this case), partial or total destruction of the real robotized system, and even human lives due to initial inexperience of the workers or students in managing these types of systems (Ortiz, J. G. 2011; Alimisis, D. 2012; Urrea, C., & Kern, J. 2011a; Urrea, C., & Kern, J. 2011b; Urrea, C., *et al.* 2011c; Urrea, C., & Kern, J. 2011d; Urrea, C. *et al.* 2012a; Urrea, C., & Kern, J. 2012b; Urrea, C., & Muñoz, J. 2013; Urrea, C., & Kern, J. 2013).

2. INNOVATION THAT WILL BE IMPLEMENTED

Innovation that will be implemented consists in the following: the teacher of a FRI course will make a careful, well planned and constant orientation to student learning, and will also reinforce the development of their critical thought. Initially, the teacher will give his students theoretical contents related to that course. In the lecture room, the students will form work teams that allow them to contrast their own individual knowledge building experience with that of all the remaining members of the course. The students will be able to represent the behavior of real robotized manipulators by means of the modular development of a graphic simulator –that will be made by the students grouped in couples– in which the characteristic parameters of the robotized manipulators to be represented (link length, mass, inertia, etc.) can be adjusted by means of an intuitive graphic interface. The design and implementation of simulation modules of industrial type robotized systems will allow students to be trained in a simple, enjoyable manner, allowing errors and learning from them, before working directly with real robots in the pedagogical, academic/research or labor world, with the associated expenses and, above all, the intrinsic dangers.

3. EVALUATION OF KNOWLEDGE BUILDING

After the implementation of the innovation described in the previous section, an analysis will be made of the students' learning results in a course on the Foundations of Industrial Robotics at the DIE-UdeSantiago, identifying, evaluating and valuing the impacts that may occur as a consequence of the activities carried out in that course. Also, it is indispensable to measure the impact of the innovation that will be implemented by means of an evaluation model whose results also allow valuing and reorienting the effectiveness of the teacher training strategies implemented in this course. Therefore, the following is considered:

- Making a diagnosis of the knowledge level of the students as they start a FRI course, orienting the development of the rest of the course.
- Establishing a systemic model to evaluate the impact of the innovations.
- Classifying the innovations documented by types, modalities and impact level.
- Establishing chronological frameworks and degrees of the scope of the innovations.
- Measuring the impact of the innovations based on their extension and depth.
- Preparing a proposal of indicators to measure the impact of the innovations.
- Designing instruments that consider the dimensions of teaching quality, to evaluate the impact of the innovations.

4. DIMENSION AND SUBDIMENSIONS OF THE IMPACT

The settings in which the incidence of the innovation that will be implemented will be evaluated, linked preferentially with the teaching-learning processes, are specified in Table 1.

Table 1. Dimension and subdimensions of the impact

Dimension	**Subdimensions**
• Learning results	• Orientation toward learning
	• Critical thought

The learning results refer to what the students must foreseeably know, understand, and be capable of doing after finishing successfully a course on the Foundations of Industrial Robotics. In its formulation, the following aspects must be taken into account:

- Being related with the competitions selected for the course.
- Adapting to its level, since the learning results vary depending on the course.
- Be enunciated in order to facilitate verifying the degree of acquisition by the students.

Orientation toward learning is the way in which the teacher directs and guides his activities toward his students' learning, establishing mechanisms and processes that guarantee their efficient development and continuous improvement, supported by the fact that the student is in a permanent learning process, both at school and in the informal setting. In this process individual differences come into play, and many students find difficulties for adequate learning.

Critical thought is the ability to think correctly, adequately and applying all the potentialities of human beings to analyze reality; in this case related with the area of industrial robotics and all its potentialities.

5. IMPACT INDICATORS

The specific aspects to be evaluated, which are derived from the dimension or subdimensions mentioned in the previous section, are those presented in Table 2.

Table 2. Impact indicators

Orientation toward learning	Critical thought
• Student motivation for learning	• Development of autonomy
• Active participation in class	• Promotion of thinking skills
• Non-mechanized learning	• Promotion of research and innovation in general
• Deepening the subjects	

6. GENERAL CHARACTERISTICS OF THE EVALUATION OF KNOWLEDGE BUILDING

In this section the kind of study, approach, design, stages, participants and procedures that will be used to evaluate the impact of the innovation that will be implemented are described.

Kind of study: Descriptive.

Approach: Qualitative, allowing the data to be examined scientifically, or more specifically numerically.

Design: Quasi-experimental, constituted of constructs, variables, indicators and indices, without control group, with a significant sample population and with recollection of the information by means of *tests* (with pre- and post-*tests*). This design is prepared before implementing the innovation, so that corrective actions may be applied in the sampling stage, since the design is conditioned to the implementation time of the innovation.

Selection parameters of the participants or samples: Since the design is quasi-experimental, chance will not be used to form the work group because all the students in the course will participate in this activity (10 students as study subjects, approximately).

Stages:

I. Decide how many independent and dependent variables must be included in the quasi-experiment. The variables needed to test the hypothesis, achieve the objectives and answer the research questions will be considered.
II. Choose the manipulation levels of the independent variables and transform them into experimental treatments.
III. Develop the instrument or instruments for measuring the dependent variables.
IV. Select the sample of people for the experiment, which will correspond to study subjects (10 students, approximately).
V. Plan how the subjects participating in this experiment will be managed, preparing a critical route that specifies, step by step, what the study subjects will do since the time they get to the site of the experiment (classroom/laboratory) until they leave.
VI. Apply the pre-*tests*, the corresponding treatments, and the post-*tests*.

Participants: The students will take a course on the Foundations of Industrial Robotics of the DIE-UdeSantiago, under the orientation of a teacher who will also initially give them the theoretical contents dealing with the course.

Information gathering procedures: A census sample will be used considering all the components of a FRI course. Notes will be taken on the development of the quasi-experiment and a detailed logbook will be kept of everything that happens throughout it, in order to assist in analyzing the possible influence of strange variables in this study, making it an invaluable material for interpreting the results.

The materials that the students will use are: Study notes provided by the teacher; technological resources such as: computers, digitalized documents, word processor, Internet search engines, and software for modeling physical phenomena (MatLab/Simulink, http://www.mathworks. com/products/matlab/pricing_licensing.html).

7. TECHNIQUES AND INSTRUMENTS

Measuring the impact level of the innovation that will be implemented considers:

- The proposal presented by Biggs and Collis in 1982 (*Evaluating the Quality of Learning: the* SOLO *taxonomy*), which allows the evaluation of the different levels of structural complexity of the learning results achieved by the students of the FRI course, because this taxonomy (*Structure of the Obseved Learning Outcomes*) allows classifying and evaluating the result of a learning task as a function of its structural organization.

- The analysis model presented by Eckel and Kezar in 2003, in which the innovations are distributed according to the intermediate spaces, given the pertinence of this already tested and validated tool for these kinds of studies, *i.e.*: Eckel and Kezar (2003, cited by Zabalza, M. A. 2003-2004, p. 127).

These tools will be complemented with the following questionnaire developed on the basis of the *Study Process Questionnaire* (SPQ) delivered by (Biggs, J. *et al.* (2001), http://chtl.hkbu.edu.hk/fre/SPQ_Questionnaire.pdf), but adapted by the authors of the present paper with the purpose of collecting better the information on the impact of the innovation that will be implemented for each of the established indicators, in agreement with the selected approach and the defined stages:

SECTION I: IDENTIFICATION DATA

Date:	**/ /**

Mark with an **x** the proper alternative.

Gender:	**F**	**M**

Course	**F**	**O**	**U**	**N**	**D**	**A**	**T**	**I**	**O**	**N**	**S**		**O**	**F**		**I**	**N**	**D**	**U**	**S**	**T**	**R**	**I**	**A**	**L**
								R	**O**	**B**	**O**	**T**	**I**	**C**	**S**										

Professor																									

SECTION II: ANLYSIS SURVEY AND DIMENSIONS

Below you will find a set of statements with which you can express your degree of agreement or disagreement using the following options:

DNA	Definitely do Not Agree
D	Disagree
A/D	Neither Agree nor Disagree
A	Agree
DA	Definitely Agree

Mark with an $\boxed{x}$ the choice that expresses most precisely your opinion with respect to each statement.

	DNA	D	A/D	A	DA
1. I think that the best way of passing an exam is to try to memorize answers to questions that will probably be in it.					
2. I learn some things mechanically going over them again and again until I memorize them, even though I don't understand them.					
3. It makes no sense to study the material that will probably not be in the exam.					
4. I think that it is not useful to study topics in depth. That only causes confusion and makes you lose time, when all you need is to become familiarized with the topics to pass them.					
5. I generally study only what is established, because I believe that it is unnecessary to do extra things.					
6. I can pass most of the formal evaluations by memorizing key parts of the topics, and not trying to understand them; I think that it is unnecessary to do extra things.					
7. I think that the teachers should not expect the students to spend much time studying matter that is known not to be in the exam.					
8. I only study seriously what we see in class or what is in the course's program.					
9. If I don't find this course interesting I make a minimum effort.					
10. My objective is to pass the course doing as little work as possible.					
11. I devote a large part of my free time to gather more information on interesting topics already dealt with.					
12. Most of the new topics seem interesting to me and I often spend extra time trying to get more information on them.					
13. I self-evaluate myself in important topics until I understand them fully.					
14. I must work a lot on a topic to be able to reach my own conclusions; only then I feel satisfied.					
15. To me it does make sense to review most of the reading recommended in class.					
16. Sometimes studying gives me a feeling of deep personal satisfaction.					
17. I go to most of my classes with questions in my mind to which I am looking for answers.					
18. I feel that actually any topic can be interesting once I get to work on it.					
19. I think that studying academic topics can sometimes be as thrilling as a good novel or movie.					
20. I work hard on my studies when I believe that the material is interesting.					
21. My interest in learning is awakened mainly when a course has been well planned and the teacher motivates me in class.					
22. I find that laboratory experiments allow me to understand better the theory delivered by the teacher.					
23. To carry out theoretical/practical experiments is more interesting than studying theory and doing practice separately.					
24. I am interested in focusing my learning thinking on the relation that it will have in my possible future labor world.					
25. I believe that it is better to perform theoretical/practical experiments together with my classmates than individually.					
26. The combination of theory and practice taking place at the same time motivates my participation in class.					
27. The orientation of this theoretical/practical course motivates my autonomous development for learning.					
28. I believe that the interaction of theory and practice, together with the dynamic exchange of ideas with my classmates, will promote the development of thinking skills.					
29. I feel that combined theoretical and practical work promotes my interest in research and innovation.					

8. EXPECTED RESULTS AFTER THE IMPLEMENTATION

The main results expected from the students taking the course, after the implementation of the innovation, are:

- Integrating theoretical and practical knowledge in the robotics field.

- Making adequate use of specific mathematical representations of this discipline.
- Learning and interpreting correctly the graphic information delivered by a graphic simulator designed and implemented by the students themselves.
- Passing from the paradigm of objectivity to that of reflexivity.
- Producing knowledge in the context of its application.
- Getting confidence and safety in the later management of real robotized systems.

The above is summarized in making improvements in significant and deep learning by the students in a FRI course of the DIE-UdeSantiago, because quality teaching is closely related with deep learning by the students who receive it, and this alternative is highly demanding, difficult, complex and challenging, obviously requiring rigorous training of its protagonists.

9. CONCLUSION

The methodological process of assessing the experiencing knowledge building through the simulation environments of manipulator robots in a Foundations of Industrial Robots course aspires to get more activity of students of intellectual character and sharpening the sensory characteristics. The settings that allow the students to build knowledge from the design and implementation of a graphic simulator were presented. The specific aspects to be evaluated, which were derived from the definition of the impact dimensions or subdimensions are pointed out. The kind of study, approach, design, stages, participants, and procedures to be used to evaluate the impact of the innovation that will be implemented were described. The techniques and instruments for measuring the impact level of that innovation were adapted and specified, and the main results that the students are expected to achieve after the implementation of a Foundations of Industrial Robots course were described. Inductive learning and learning by a guided discovery by students should ensure good designs and implementation of graphic simulations of real robotized manipulators. The assessing of the impact of innovations is expected to reinforce the knowledge building process of students of electrical engineering at the Universidad de Santiago de Chile.

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BIOGRAPHICAL INFORMATION

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