EXPERIENCING KNOWLEDGE CONSTRUCTION OF STUDENTS IN THE FIELD OF INDUSTRIAL ROBOTICS OF THE DIE-UdeSantiago de Chile[1]

Claudio Urrea, Manuel Vega

Department of Electrical Engineering, Universidad de Santiago de Chile,
Santiago, Chile

ABSTRACT

This paper describes the process that enabled the assessment of experiencing knowledge construction processes in simulation research on robotic manipulators by students in a course of Foundations of Industrial Robotics in engineering, based on design and implementation of a simulation environment of actual robotic manipulators.
In general, this research favored inductive learning and learning by guided discovery by students, ensuring the design and experimentation of a number of didactic situations that allowed them to build their knowledge. For this reason, this research considers cognitivist theories of teaching and learning, demanding – from the students – greater intellectual activity and sharpening their sensory characteristics. Within this context, the mistakes made during the learning process are seen as an important factor in the knowledge construction process, because being wrong motivates the student to try different alternative solutions. Some of the studied learning situations are the following:

- Integration of different areas of knowledge, because robotics is a multidisciplinary science.
- Operations with objects that may be manipulated, favoring the transition from abstract to concrete.
- Appropriation of graphic language, as if it were mathematical language.
- Operation and control of different variables in a synchronic manner.
- Systematic thought development.
- Constructing and testing students' own knowledge acquisition strategies through pedagogical orientation.

KEYWORDS

Integrated Learning Experiences, Conceive, Design, Implement, Operate, Design-Build Experience, Standards: 5.8

1. INTRODUCTION

Educational robotics can be understood as a way of doing, understanding and learning reality. It constitutes a field of action with the object of generating learning environments based mainly of students' activity. One of the most interesting factors is the integration of different areas that occurs naturally. In this innovative learning environment, students use most of their time simulating phenomena and mechanisms, designing and building

[1] DIE-UdeSantiago de Chile: Departamento de Ingeniería Eléctrica of the Universidad de Santiago de Chile.

prototypes, that are micro-representations of the surrounding technological reality, or are their own inventions. One of the benefits of educational robotics is the generation of interesting and motivating learning environments, where the role of the teacher is that of a facilitator, and the student is an active manager, promotes transversality in the curriculum, there different knowledge concurs in solving the problems at hand, and also enables establishing relations and representations. This paper, therefore, focuses on the evaluation of building knowledge carried out in educational robotics as means for learning, where the main motivation is he design and construction of their own creations that first occur in the mind, and later, physically. This is where the design and implementation of industrial-type robotic simulation system modules are proposed to enable "experiencing" the construction of knowledge. This will enable last year students of the career of Electrical Engineering at DIE-UdeSantiago de Chile, specifically the students of the course of Foundations of Industrial Robotics, to acquire the tools to enable them to graphically – although very realistically and safely – the behavior of robotized manipulators which. In direct operating conditions (working with real robots), this may result in accidents for operators in industrial environments (in this case, students), real partial or total destruction of the robotizes system, and even human loss, due to initial inexperience on the part of the operators or students in operating these types of systems.

2. INSTITUTIONAL EDUCATION MODEL

The Institutional Educational Model of Universidad de Santiago de Chile considers the students' formative process that which gives meaning and purpose to our university work. As seen in the diagram of Figure 1, considering the student as the center of the formative process, teaching has a primary role, understanding that the construction of knowledge is carried out by a series of mechanisms that consider teacher mediation and students' individual work.

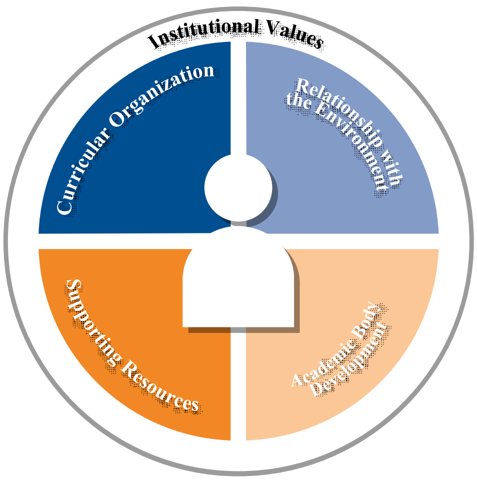

Figure 1. Diagram of the Institutional Education Model

According to the institutional seal, those graduating from Universidad de Santiago de Chile must:

- Work as a team toward a common objective. This implies assuming an active role in organization and distribution of activities, and taking responsibility for task development of their competence and demonstrating a respectful attitude toward the team members.
- Exercise leadership within the performance environment, being capable of coordinating, directing and monitoring the work of others in a way that is proactive, projective and strategic.

- Autonomously learn the knowledge or skills that are necessary to meet the challenges that are presented in performing their functions, seeking permanent improvement in professional or academic performance.
- Develop a permanent focus on innovation and entrepreneurship in new challenges in the exercise of their professional or academic role, seeking constant improvement of their reality.
- Take on an ethic stance in performing and making decisions in professional, academic and citizenship areas.
- Act based on a principle of social responsibility and citizenship awareness in the exercise of any professional or academic activity.
- Develop full knowledge of their mother language and encourage the knowledge of other languages and general culture of where they are inserted.
- Demonstrate adaptability to conditions and characteristics of different professional or academic scenarios which they may face.

3. INNOVATION TO BE IMPLEMENTED

The innovation to be implemented consists of the following: The teacher of the course Foundations of Industrial Robotics performs a careful, well-planned and consistent orientation toward student learning, and, additionally, enhances development of their critical thinking. Initially, the teacher delivers theoretic contents related to the course to the students. In the classroom, students form in pairs, allowing them to compare their own experiences in building individual knowledge with the experience of the rest of the members of the classroom. Students represent the behavior of real robotized manipulators through modular design of a graphic simulator – which the students do in pairs – that may be adjusted to the characteristic parameters of robotized manipulators to be represented (length of links, mass, inertia, etc.) through an intuitive graphic interface. Design and implementation of the simulation modules of industrial-type robotized systems enable training students in a way that is easy and fun, allowing them to make mistakes and learn from them, before working directly with real robots in the teaching, academic/research or work environment, with economical costs, and most of all, due to the intrinsic danger associated to it.

4. MODULAR DESIGN OF THE GRAPHIC SIMULATOR

The teacher proposes that the students design a graphic simulator for industrial robots with N Degrees Of Freedom (DOF) using software tools such as MatLab/Simulink, developed by MathWorks, y MathType, developed by DesignScience.

In particular, the teacher specifies the type of robot and the N value that represents the number of DOF. For example, a KUKA robot with $N = 5$ may be chosen, such as the one presented in Figure 2. This KR AGIULUS five KUKA robot has been designed with five axes for especially high work speeds. At the same time, it offers maximum precision. The KR AGILUS five uses little space and may be mounted on the floor and on the ceiling, which makes this robot extremely adaptable.

Figure 2. KUKA robot Model KR 6 R700 fivve (KR AGILUS) with 5 DOF
Source: www.kuka-robotics.com/es/

From this information, the students, organized in working pairs, from the following diagram given by the professor (see Figure 3) choose a block to solve. Following the logical sequence of the flowchart, from start to finish, all the students fulfill the global objective of designing a graphic simulator for a particular industrial robot.

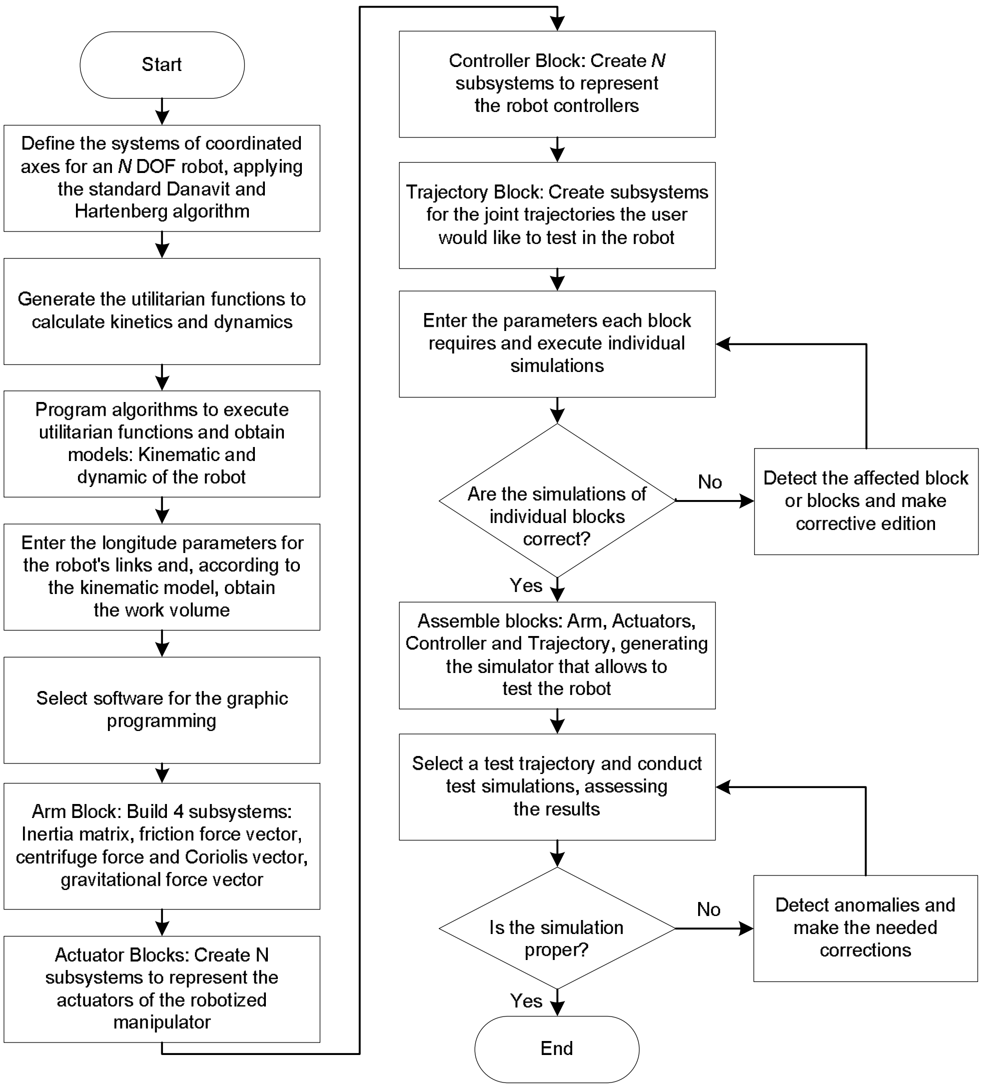

Figure 3. Flowchart. Design of a graphic simulator for an industrial robot

5. EVALUATION OF THE KNOWLEDGE CONSTRUCTION

After designing the specified graphic simulator, the learning results of the students of the course Foundations of Industrial Robotics UdeSantiago de Chile are analyzed, identifying, evaluating and valuing the impact that may occur as consequence of the activities carried out in the course. At the same time, the impact of innovation implemented through an assessment model. These results also enable valuating and redirecting the effectiveness of the teaching strategies implemented in this course. Therefore it is considered to:

- Prepare an assessment of the level of learning of the students when they enter the course of Foundations of Industrial Robotics, which will guide the development of the rest of the course.
- Establish a systemic model to assess the impact of innovations.
- Classify documented innovations by types, modalities and impact levels.
- Establish time frames and degrees in the scope of the innovations.
- Measure the impact of innovations from the breadth and depth.
- Develop a set of indicators to measure the impact of the innovations.
- Design instruments considering the dimensions of teaching quality, to assess the impact of the innovations.

6. DIMENSIONS AND SUB-DIMENSIONS OF IMPACT

The following table specifies the areas where incidence of the innovation to be implemented is evaluated. These areas are related to some processes of teaching/learning linked to the Institutional Educational Model of Universidad de Santiago de Chile, described in Section 2.

Table 1. Dimension and sub-dimensions of impact

Dimension	Sub-dimensions
• Learning results	• Teamwork
	• Autonomous learning

The learning results correspond to some of the features that must be part of the profile of the students who pass a course in Foundations of Industrial Robotics. Thanks to these, it will contribute in developing attributes that are part of the Institutional Seal of graduates from Universidad de Santiago de Chile. The learning results, studied particularly in this paper, explicit the general meaning of the course with regard to the graduation profile of the professional career (Electrical Engineering, in this particular case), the modality and how it relates to other subjects.

7. IMPACT INDICATORS

Table 2 shows specific aspects for evaluation that are related to theoretical and practical tools that enable students decide when faced with problems of automation for industrial processes linked to industrial robotics, that derive of the dimensions or sub-dimensions indicated in the section above.

Table 2. Impact indicators

Teamwork	Autonomous learning
• Develop a common objective	• Acquire the necessary knowledge or skills to respond to challenges that may arise during the performance of their functions.
• Take on an active role in the organization and distribution of activities.	• Seek continuous improvement of their professional or academic performance.
• Be responsible for the development of the tasks of their competence.	
• Show a respectful attitude toward the team.	

8. GENERAL CHARACTERISTICS OF THE EVALUATION OF THE CONSTRUCTION OF KNOWLEDGE

In this section, the type, focus, design, stages, participants and procedures of the study to be used to assess the impact of the innovation to be implemented is described.

Type of Study: Descriptive.

Focus: Qualitative, to enable examining the data scientifically, or more specifically, numerically.

Design: Quasi-experimental, made up of constructs, variables, indicators and indices, without a control group, with a significant population sample and data collection through tests (with pre- and post-tests). This design is made before implementing the innovation. Thanks to this, corrective actions may be applied in the sampling stage, because the design is conditioned to the implementation time of the innovation.

Selection Parameters for Participants or Sample: Since the design is quasi-experimental, chance is not used to form the working team, because all of the students of the course participate in this activity (approximately 16 students as subjects of study).

Stages:

I. Decide how many dependent and independent variables should be included in the quasi-experiment. The variables needed to test the hypotheses, meet the objectives and answer the research questions are considered.

II. Choose the level of manipulation of independent variables and translate them into experimental treatments.

III. Develop an instrument or instruments to measure the dependent variable(s).

IV. Select the sample of people for the experiment, which correspond to subjects of study (approximately 16 students).

V. Plan how to handle subjects participating in this experiment, developing a critical path specifying what the subjects of the study will do, step by step, from the time they reach the location of the experiment (classroom/laboratory) until they leave.

VI. Apply pre-tests, the respective treatments and post-tests.

Participants: It is applied to students of the course of Foundations of Industrial Robotics DIE-UdeSantiago de Chile, who are oriented by a teacher who additionally delivers initial theoretical contents related to the course.

Procedures for Gathering Information: A census sample considering all the members of a course of Foundations of Industrial Robotics is used. Notes are taken of the development of the quasi-experiment. A detailed log of everything that has occurred during the experience is kept, which is useful for the analysis of possible influence of external variables to this study and constitutes an invaluable tool for the interpretation of results.

The materials to be used by the students are: Textbooks delivered by the subject teacher; technological resources such as: Computers, digitalized documents, word processors, software to model physical phenomena (MatLab/Simulink, http://www.mathworks.com/products/matlab/pricing_licensing.html) and internet search engines.

9. TECHNIQUES AND INSTRUMENTS

To measure the level of impact of the innovation to be implemented, the following is considered:

- The proposal presented by Biggs and Colins in 1982 (Evaluating the Quality of Learning: The SOLO taxonomy), designed to measure different levels of structural complexity in the learning results reached by the students of a course of Foundations of Industrial Robotics, given that this taxonomy (Structured of the Observed Learning Outcomes) enables classifying and evaluating the result of a learning task in terms of its structural organization.
- The analysis model presented by Eckel and Kezar in 2003, in which the innovations are distributed according to gaps, given the pertinence of this tool that has been tested and validated for this type of study, i.e.: Eckel and Kezar (2003, cited by Zabalza, M. A. 2003-2004, p. 127).

These tools are supplemented by the following questionnaire developed based on Study Process Questionnaire (SPQ), delivered by Biggs, J. *et al* (2001), http://chtl.hkbu.edu.hk/fre/SPQ_Questionnaire.pdf), but which has been adapted by the authors of this paper in order to better collect the information on the impact of the innovation to be implemented for each one of the established indicators, and is coherent with the selected focus and the defined stages.

At the end of the Foundations of Industrial Robotics course, each student responds the following questionnaire:

SECTION I: IDENTIFICATION DATA

Date:	/ /

Mark the corresponding alternative with an x.

Gender	**F**	**M**

Subject	**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**								

Teacher																							

SECTION II: SURVEY AND ANALYSIS DIMENSIONS

Next, a set of statements is presented, where the degree of agreement or disagreement may be expressed from the following options of answers:

TD	**Totally Disagree**
D:	**Disagree**
A/D	**Neither Agree nor Disagree**
A:	**Agree**
TA:	**Totally Agree**

Mark the alternative that most precisely expresses your appreciation of each statement with an X.

		TD	D:	A/D	A:	TA:
1.	I think the best way to pass an exam is to memorize the answers to the questions that will probably be asked.					
2.	I learn some things mechanically, reviewing them over and over until I memorize them, although I don't understand them.					
3.	It makes no sense to study the material that probably will not be in the test.					
4.	I think it is not useful to study topics in depth. This only leads to confusion and is a waste of time, when all you need is to be familiarizes with the topics to pass.					
5.	Generally, I limit to studying only what is established because I don't think it is necessary to anything extra.					
6.	I can pass most of the formal tests by memorizing key parts of the topics and not by trying to understand them. I think it is not necessary to do anything extra.					
7.	I think teachers should not expect students to study materials that will not be evaluated in the test.					
8.	I only seriously study what is seen in class or what is in the course program.					
9.	If I don’t think the course is interesting, I make the minimum effort.					
10.	My goal is to pass the course with as little work as possible.					
11.	I use a lot of my free time to gather more information on interesting topics that have been covered.					
12.	Most of the new topics seem interesting and I frequently spend time trying to find information on them.					
13.	I assess myself on important topics until I fully understand them.					
14.	I have to work a lot on a topic in order to reach my own conclusions; only this way I feel satisfied.					
15.	It makes sense to me to revise most of the reading recommended in class.					
16.	Sometimes studying makes me feel deep personal satisfaction.					
17.	I attend most of the classes with questions in mind that I am looking for answers.					
18.	I really feel that any topic can be interesting once I start to work on it.					
19.	I think studying academic topics can, on occasions, be as exciting as a good novel or a movie.					
20.	I work hard in my studies when I think the material is interesting.					
21.	My interest in learning mainly arises from a well-planned course and the motivation from the teacher in class.					
22.	I think laboratory experience allow me to better understand the theory provided by the teacher.					
23.	Performing theoretic/practical experiences is more interesting than studying theory and doing practice separately.					
24.	I am interested in focusing my learning thinking about the relation these have with my possible future world of work.					
25.	I think it is better to conduct theoretic/practical experiences with my classmates than individually.					
26.	The combination of theory and practice that is carried out simultaneously motivates my participation in class.					
27.	The orientation of this theoretic/practical course motivates my autonomous development in learning.					
28.	I think the interaction between theory and practice; along with the dynamic exchange with my classmates foster the development of my thinking skills.					
29.	I fell that theoretic and practical works combined promote my interest for research and innovation.					

10. EXPECTED RESULTS AFTER THE IMPLEMENTATION AND SURVEY

The main expected results for students to achieve in this course, after the implementation of the innovation are:

- Integrate theoretical and practical knowledge in the area of robotics.
- Make appropriate use of specific mathematical representations of this discipline.

- Learn to correctly interpret the graphic information provided by a graphic simulator designed and implemented by the students themselves.
- Move from the paradigm of objectivity to that of reflexivity.
- Produce knowledge in the context of its application.
- Gain confidence and security in subsequent operation of real robotized systems.

Above is summarized in achieving improvements in significant and deep knowledge of students of the Foundations of Industrial Robotics DIE-UdeSantiago de Chile course, because quality teaching is intimately related to deep learning of the students receiving it, which is highly demanding, difficult, complex and challenging. This obviously requires rigorous preparation of its protagonists.

Results obtained from the anonymous application of the survey to the 16 students of the course:

Question number	TD	D	A/D	A	TA
1	14	2	0	0	0
2	10	4	1	1	0
3	13	3	0	0	0
4	12	2	1	1	0
5	11	2	2	1	0
6	14	2	0	0	0
7	13	3	0	0	0
8	13	3	0	0	0
9	10	3	2	1	0
10	11	2	2	1	0
11	0	1	1	2	12
12	0	0	1	2	13
13	0	0	1	4	11
14	0	0	2	4	10
15	0	0	0	0	16
16	0	0	0	1	15
17	0	0	0	0	16
18	0	0	0	1	15
19	0	0	0	2	14
20	0	0	0	1	15
21	0	0	0	0	16
22	0	0	0	1	15
23	0	0	0	0	16
24	0	0	0	0	16
25	0	0	0	4	12
26	0	0	0	0	16
27	0	0	0	0	16
28	0	0	0	0	16
29	0	0	0	0	16

11. CONCLUSIONS

Through this work, a methodological process was described for the assessment of the experiencing of knowledge building processes in simulation environments of manipulating robots in students of the course Foundations of Industrial Robotics of the Department of Electrical Engineering of the Universidad de Santiago de Chile. The methodological proposal, cognitive theories of teaching and learning were considered, that demand, from the students, greater intellectual activity and sharpening their sensorial characteristics, thanks to the design and implementation of a graphic simulation environment of real robotized manipulators. This proposal privileged inductive learning and guided discovery of the students, securing the design and implementation of a set of teaching situations that enable students to build their own knowledge. The areas in which the design and implementation of a graphic simulation environment of real robotized manipulators was assessed, enabling students to build knowledge (implemented innovation). These areas are preferably linked to teaching/learning processes. Specific aspects to be assessed were indicated, deriving from the definitions of the dimensions and sub-dimensions of impact. The type, focus, design, stages, participants and procedures of the study to be used to assess the impact of the innovation to be implemented is described. Techniques and instruments were adapted and specified to measure the level of impact of the innovation and the main expected results for students to achieve after the implementation of a course in Foundations of Industrial Robotics were described. From the results of the applying the anonymous survey applied to the 16 students, the success in implementing this innovation are clearly confirmed. Thus, we were able to contribute with a set of attributes that should be part of the fundamental profile of graduates from Universidad de Santiago de Chile, in order for them to provide distinctively to the development of the country.

BIBLIOGRAPHIC REFERENCES

Alimisis, D. (2012). "Robotics in Education & Education in Robotics: Shifting Focus from Technology to Pedagogy", In Proceedings of the 3rd international conference on Robotics in Education, RiE2012.September 2012, pp. 7-14. MatfyzPress, CzechRepublic.

Backhouse, R., Grünewald, I., Letelier, M., *et al.* (2007). Un modelo de sistema institucional de aseguramiento de la calidad. En Ayarza, H., Cortadillas, J., González et al. (eds.) Acreditación y dirección estratégica para la calidad. Santiago de Chile: CINDA.

Biggs, J., & Colins, K. (1982).Evaluating the Quality of Learning: the SOLO taxonomy. New York: Academic Press.

Biggs, J., Kember, D., & Leung, D. (2001). The revised two-factor Study Process Questionnaire: R-SPQ-2F, British Journal of Educational Psychology, 71, 133-149.

Biggs, J., & Tang, C. (2007).*Teaching for Quality Learning at University* (3rd edn) Buckingham: SRHE and Open University Press.

Comité Español de Automática (CEA). (2012). El Libro Blanco de la Robótica en España. http://www.ceautomatica.es/og/robotica/libro-blanco-de-la-robotica

DiasSobrinho, J. (2006). Acreditación de la Educación Superior en América Latina y el Caribe. En La Educación Superior en el Mundo 2007. Acreditación para la garantía de la calidad: ¿Qué está enjuego?, Madrid/Barcelona: Global University Network forInnovation (GUNI/UNESCO, Ediciones Mundi-Prensa.

DIDE (Dirección de Investigación y Desarrollo Educativo). (2004). Vicerrectorado Académico, Instituto Tecnológico y Estudios Superiores de Monterrey "El Aprendizaje Basado en Problemas como técnica didáctica". http://www.ub.es/mercanti/abp.pdf

Ortiz, J. G. (2011). Sistema de Indicadores y Metodología de Evaluación para la Robótica en el Aula (tesis de maestría). Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Chihuahua, México.

Ortiz, J. G., Bustos, R., & Ríos, A. (2011). "System of Indicators and Methodology of Evaluation for the Robotics in Classroom".En Proceedings of 2nd International Conference on Robotics in Education (RiE 2011). (63-70). Vienna, Austria, September, 2011. INNOC - Austrian Society for Innovative Computer Sciences.

Parker, L. E. (2008).Multiple mobile robot systems. Handbook of Robotics, Springer, 921-941.

Perkins, D. (2006). Hacia una cultura de pensamiento. Conferencia, Buenos Aires, Argentina. http://www.ellibro.com.ar/32feria/educativas/html/archivo/conferencias/perkins_david.html

Petrovic, P. (2012). *"Having Fun with Learning Robots"*, In Proceedings of the 3rd international conference on Robotics in Education, RiE2012. September 2012., pp. 105-112. MatfyzPress, Czech Republic.

Sirvanci, M. (2004). Critical issues for TQM implementation in higher education. The TQM Magazine, 16 (6), pp. 382-386.

Tójar, J. C., & Matas, A. (2005). El proceso de innovación educativa en la formación permanente del profesorado universitario: un estudio multicaso. *Revista española de pedagogía*, año LXIII, Nº 232, 529-552. Recuperado en septiembre de 2011 de: http://revistadepedagogia.org/2007060265/vol.-lxiii-2005/n%C2%BA-232-septiembrediciembre-2005/el-proceso-de-innovacion-educativa-en-la-formacion-permanente-delprofesorado- universitario-un-estudio-multicaso.html

Urrea, C., & Kern, J. (2011a). "Intelligent Mechatronics". Chapter: "Development of a Simulation Environment Applied to the Study of Fault-Tolerant Control Systems in Robotic Manipulators. Theoretical and Practical Comparisons", INTECH, edited by Ganesh R. Naik. ISBN: 978-953-307-300-2. 248 pages.

Urrea, C., & Kern, J. (2011b). "Multi-Robot Systems, Trends and Development". Chapter: "Modeling, Simulation and Control of 3-DOF Redundant Fault Tolerant Robots by Means of Adaptive Inertia", INTECH, edited by Toshiyuki Yasuda and Kazuhiro Ohkura. ISBN: 978-953-307-425-2. 586 pages.

Urrea, C., Kern, J., &Hortiz, H. (2012a), "Robotic Systems. Applications, Control and Programming". Chapter: "Performance Evaluation of Fault-Tolerant Controllers in Robotic Manipulators", INTECH, edited by Ashish Dutta. ISBN: 978-953-307-941-7. 638 pages.

Urrea, C., & Kern, J. (2012b). "Modeling, Simulation and Control of a Redundant SCARA-Type Manipulator Robot", International Journal of Advanced Robotic Systems Robot Manipulators. Vol. 9(58), pp. 01-14.

Urrea, C., & Muñoz, J. (2013)."Path Tracking of Mobile Robot in Crops", Journal of Intelligent and Robotic Systems. Print ISSN: 0921-0296, Online ISSN: 1573-0409; Publisher: Springer Netherlands. DOI: 10.1007/s10846-013-9989-1. http://link.springer.com/article/10.1007%2Fs10846-013-9989-1

Urrea, C., & Kern, J. (2013). "Controladores Tolerantes a Fallas en Manipuladores Robóticos. Evaluaciones de Desempeño (Fault-Tolerant Controllers in Robotic Manipulators. Performance Evaluations). IEEE Latin America Transactions Vol. 11(6), pp. 1319-1325. ISSN: 1548-0992. http://www.ewh.ieee.org/reg/9/etrans/ieee/issues/vol11/vol11issue6Dec.2013/06Urrea.htm

Urrea, C., & Kern, J. (2014). "Development of an Electronic Controller Applied to a Robotized Manipulator Through The SPI Protocol". JökullJournal Vol. 64(4). ISSN: 0449-0576.

Zabalza, M. A. (2003-2004). Innovación en la enseñanza universitaria. Contextos educativos, 6:7, 113-136. Recuperado en septiembre de 2011 de: http://dialnet.unirioja.es/servlet/fichero_articulo?codigo=1049473

BIOGRAPHICAL INFORMATION

Claudio Urrea, Ph.D. is currently Professor at the Electrical Engineering Department, Universidad de Santiago de Chile, from 1998. He has developed and implemented a Robotics Laboratory, where intelligent robotic systems are development and investigated. He is currently Director of the Doctorate in Engineering Sciences, Major in Automation, at the Universidad de Santiago de Chile.

Manuel Vega, M.Sc. is a Senior Lecturer in the Electrical Engineering Department at the Universidad de Santiago de Chile. He obtained his Master Degree at Mc Gill University, Canada. His teaching interests include digital electronics, microcomputers and robots. He has been actively involved in the design and development of introduction to engineering courses.

Corresponding author

Dr. Claudio Urrea
Universidad de Santiago de Chile
Avenida Ecuador 3519
Estación Central, Santiago, Chile.
56-2-2718 33 50
claudio.urrea@usach.cl