15è Premi a la Qualitat en la Docència Universitària

2012

Trajectòria Docent

al professor Miguel Cervera Ruiz

Iniciativa Docent

Concepció, disseny, implementació i operació de sistemes i productes del món real de l'itinerari d'assignatures de projectes, dirigit per Ramon Bragós

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Consell Social

El Premi UPC a la Qualitat en la Docència Universitària va ser instituït pel Consell Social de la Universitat Politècnica de Catalunya l'any 1998 amb la finalitat d'incentivar l'excel·lència de la funció docent mitjançant el reconeixement exprés de l'exercici d'una activitat docent rellevant (Premi a la Trajectòria Docent) o la millora o la implantació de mètodes docents que han contribuït a la renovació i millora de la qualitat docent (Premi a la Iniciativa Docent).

Aquest llibre recull els projectes guanyadors d'ambdues modalitats de l'edició de 2012 del Premi.

El Premi a la Trajectòria Docent al professor Miguel Cervera Ruiz, del departament de Resistència de Materials i Estructures a l'Enginyeria a l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ponts de Barcelona.

El jurat va valorar diferents aspectes de l'activitat docent continuada del professor Miguel Cervera durant més de 26 anys a la UPC en tots els cicles dels plans d'estudis, que l'han convertit en un referent a l'Escola Tècnica Superior d'Enginyeria de Camins Canals i Ponts de Barcelona:

- La bona combinació d'una docència intensa i rellevant amb una recerca de qualitat i amb una especial contribució a la implantació de mètodes docents, tots tres aspectes desenvolupats amb un alt grau d'excel·lència.

- La implicació directa i activa en iniciatives de renovació i millora de la qualitat docent relacionades amb l'harmonització amb l'Espai Europeu d'Educació Superior i amb la implantació de les noves titulacions de Grau i Màster.

- L'alt grau de compromís i col·laboració, durant tota la seva trajectòria, tant amb el seu centre, com amb els seus parells i amb l'estudiantat, pel qual és molt ben valorat.

El **Premi a la Iniciativa Docent** al projecte **Concepció, disseny, implementació i operació de sistemes i productes del món real de l'itinerari d'assignatures de projectes**, dirigit pel professor Ramon Bragós, del departament d'Enginyeria Electrònica a l'Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona.

Aquesta experiència consisteix en el desenvolupament d'un itinerari d'assignatures de projectes, en base a la metodologia CDIO (Concepció, Disseny, Implementació i Operació de sistemes i productes del món real), adoptada pel centre, que facilita un aprenentatge pràctic. La metodologia defineix eines i bones pràctiques per ajudar al disseny de plans d'estudis i afegeix competències pròpies de l'exercici de l'enginyeria a les competències específiques de les matèries d'una titulació i a les competències genèriques comunes a tota la UPC.

El disseny d'estudis d'enginyeria basat en aquesta metodologia, que és reconeguda internacionalment, representa un enfocament nou dels estudis d'enginyeria, orientat a l'assoliment de competències professionalitzadores, que cerca una millor inserció de l'estudiantat en l'àmbit laboral.

Al 2008 l'Escola Tècnica Superior d'Enginyeria de Telecomunicacions de Barcelona (ETSETB) va iniciar l'adopció d'aquesta metodologia i en aquest moment té consolidada l'etapa d'implantació.

El jurat va valorar que l'experiència implica un gran nombre de professorat del centre, cosa que demostra la viabilitat de la implantació del treball per competències en el conjunt d'una titulació, amb la voluntat de coordinació del professorat, la valoració molt positiva del professorat i de l'estudiantat implicat i el fet que ha suposat incorporar la UPC a un projecte internacional que li reconeix una adaptació singular, coneguda com a model Barcelona.

Les dues candidatures han estat guardonades amb la distinció Jaume Vicens Vives a la qualitat docent universitària, que atorga la Generalitat de Catalunya (Decret 113/2011, de 9 d'octubre 2012).

15è Premi a la Qualitat en la Docència Universitària

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Trajectòria Docent

al professor Miguel Cervera Ruiz

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Consell Social

Índex

1. Memòria de candidatura

1.1. Dades personals

Nom : Miguel Cervera Ruiz

Categoria actual : Catedràtic d'Universitat

Universitat actual : Universitat Politècnica de Catalunya

Escola actual : E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona

Departament actual : Resistència de Materials i Estructures en l'Enginyeria

1.2. Títols acadèmics

- TÍtol : Enginyer de Camins, Canals i Ports
  Organisme : E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona (UPC)
  Data : Setembre de 1983
  Qualificació : Excel.lent

- TÍtol : Doctor of Philosophy in Civil Engineering
  Organisme : University College of Swansea, University of Wales, United Kingdom
  Data : Desembre de 1986

- TÍtol : Doctor Enginyer de Camins, Canals i Ports
  Organisme : Universitat Politècnica de Catalunya
  Data : Setembre de 1987

1.3. Càrrecs docents i de recerca

- Categoria : Teaching Assistant
  Organisme : Civil Engineering Department, University College of Swansea
  Periode : Octubre 1983 fins al Setembre 1986

- Categoria : Investigador contractat
  Organisme : Centre Internacional de Mètodes Numèrics en Enginyeria de Barcelona
  Periode : Octubre 1986 fins al Setembre 1987

- Categoria : Professor Titular Interí
  Organisme : E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona (UPC)
  Dedicació : Temps Complet
  Periode : Octubre 1987 fins al Febrer 1988

- Categoria : Professor Titular d'Universitat
  Organisme : E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona (UPC)
  Periode : Març 1988 fins al Juny de 1999

- Categoria : Catedràtic d'Universitat
  Organisme : E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona (UPC)
  Periode : Desde Juliol de 1999

1.4. Activitat docent

TITULACIÓ D'ENGINYER DE CAMINS, CANALS I PORTS (ETSECCPB)

- Materia : Estructures I
  Periode : Curs 1987-88.

- Materia : Estructures III
  Periode : Octubre 1987-Setembre 1997.

- Materia : Aplicacions en Enginyeria Computacional
  Periode : Desde Febrer 2000.

TITULACIONS D'ENGINYERIA TÈCNICA D'OBRES PÚBLIQUES (ETSECCPB)

- Materia : Resistència de Materials
  Periode : Des d'Octubre 1988 fins al Setembre 1997.

- Materia : Estructures
  Periode : Desde Setembre 1997 fins al Juny 2012.

- Materia : Anàlisi d'Estructures
  Periode : Desde Setembre 1998 fins al Juny 2001.

GRAU EN ENGINYERIA DE LA CONSTRUCCIÓ (ETSECCPB)

- Materia : Resistència de Materials
  Periode : Desde Gener 2012.

- Materia : Estructures
  Periode : Desde Setembre 2011.

- Materia : Càlcul d'Estructures
  Periode : Desde Setembre 2011.

CURSOS DE DOCTORAT (ETSECCPB)

- Programes : Anàlisi Estructural i Enginyeria Civil.
  Materia : Solució de problemes acoblats sòlid/fluid pel MEF.
  Periode : Febrer 1994-Juliol 1999.

- Programes : Anàlisi Estructural i Enginyeria Civil.
  Materia : Mètodes numèrics en la mecànica de sòlids no lineals.
  Periode : Desde Maig 1995.

- Programes : Anàlisi Estructural i Enginyeria Civil.
  Materia : Anàlisi Avançat d'Estructures
  Periode : Desde Gener 2001.

- Programes : Anàlisi Estructural i Enginyeria Civil.
  Materia : Càlcul Avançat en Mecànica de Sòlids mitjançant Elements Finits.
  Periode : Desde Gener 2006.

CURSOS DE MÀSTER (ETSECCPB)

- Curs : Mètodes Numèrics per Càlcul i Disseny en Enginyeria.
  Materia : Anàlisi d'Estructures
  Periode : Desde Gener 1991.

- Curs : Mètodes Numèrics per Càlcul i Disseny en Enginyeria.
  Versió a Distància.
  Materia : Anàlisi d'Estructures
  Periode : Desde Gener 2000.

CURSOS DE MÀSTER OFICIALS (ETSECCPB)

- Curs : Màster en Enginyeria Civil
  Materia : Enginyeria Estructural i de la Construcció.
  Periode : Desde Setembre 2007.

- Curs : Màster en Enginyeria Estructural i de la Construcció,
  Màster en Enginyeria Civil.
  Materia : Mecànica Avançada d'Estructures
  Periode : Desde Gener 2008.

- Curs : Màster en Enginyeria Estructural i de la Construcció.
  Materia : Mecànica Avançada de Sòlids
  Periode : Desde Gener 2008.

- Curs : Màster de Mètodes Numèrics en Enginyeria.
  Materia : Anàlisi Avançat d'Estructures
  Periode : Desde Gener 2008.

- Curs : Màster en Enginyeria Estructural i de la Construcció.
  Materia : Aplicacions en Anàlisi Estructural
  Periode : Desde Gener 2008.

CURSOS DE MÀSTER INTERNACIONALS (ERASMUS MUNDUS)

- Curs : Master of Science in Computational Mechanics, Erasmus Mundus Master Course.
  Materia : Computational Structural Mechanics and Dynamics.
  Periode : Desde Gener 2008.

- Curs : Advanced Masters in Structural Analysis of Monuments and Historical Constructions.
  Materia : Advanced Structural Analysis SA2.
  Periode : Desde Novembre 2008.

DIRECCIÓ DE TREBALLS FINAL DE CARRERA

- Projectes Final de Carrera : 6.
  Centres : E.T.S. Eng. Industrials de Terrasa (UPC),
  : E.T.S. Eng. de Camins, Canals i Ports de Barcelona (UPC).
  Periode : Desde 1997.

- Tesines d'Especialitat : 13.
  Centres : E.T.S. Eng. de Camins, Canals i Ports de Barcelona (UPC).
  Periode : Desde 1989.

DIRECCIÓ DE TESIS DOCTORALS

- Tesis Doctorals Dirigides : 6.
  Centre : E.T.S. Eng. de Camins, Canals i Ports de Barcelona (UPC).
  Periode : Desde 1993.

- Tesis Doctorals en Direcció : 15.
  Centros : E.T.S. Eng. de Camins, Canals i Ports de Barcelona (UPC).
  Periode : Desde 2007.

CURSOS I SEMINARIS IMPARTITS (ÚLTIMS 10 ANYS)

- Centre : Centre Internacional de Mètodes Numèrics en Enginyeria, Barcelona.
  Curs : VI Course on Computational Techniques for Plasticity.

Materia : Modelling of concrete problems.
Data : Setembre 2000.

- Centre : Centre Internacional de Mètodes Numèrics en Enginyeria, Barcelona.
  Curs : Curs Introductori sobre Càlcul d'Estructures pel MEF. Versió a Distància.
  Materia : Anàlisi d'Estructures
  Periode : Desde Març 2002.

- Centre : Centre Internacional de Mètodes Numèrics en Enginyeria, Barcelona
  Curs : IX Course on Computational Techniques for Plasticity.
  Materia : FE approaches to tensile fracture.
  Data : Setembre 2007.

- Centre : Universitá di Bologna.
  Seminari : Seminaris de Recerca.
  Materia : Finite Element Strategies for Tensile Fracture.
  Data : Març 2009.

- Centre : Universitá di Ferrara.
  Seminari : Seminaris de Recerca.
  Materia : Finite Element Strategies for Tensile Fracture.
  Data : Març 2009.

- Centre : Centre Internacional de Mètodes Numèrics en Enginyeria, Barcelona
  Curs : X Course on Computational Techniques for Plasticity.
  Materia : Strain localization and size effect in J2 plasticity.
  Data : Setembre 2009.

- Centre : Centre Internacional de Mètodes Numèrics en Enginyeria, Barcelona

Curs : XI Course on Computational Techniques for Plasticity.
Materia : Mixed FE formulations and strain localization.
Data : Setembre 2011.

- Centre : Centre Internacional de Mètodes Numèrics en Enginyeria, Barcelona
  Seminari : III LKAB Workshop on Simulation of Mining and Metallurgical Processes Using Particle Based Methods.
  Materia : Mixed FE formulations and strain localization.
  Data : Octubre 2011.

1.5. Participació en projectes docents internacionals

Development of advanced training activities and educational software in computational engineering.
Presentat i aprovat en la convocatòria COMETT II de 1990
Referència: 90/1/5387/Ccp
Periode: Febrer 1991-Gener 1995

Curs bàsic i avançat en enginyeria computacional emprant software educatiu.
Presentat i aprovat en la convocatòria COMETT II de 1994
Referència: 94/1/8259/Ca
Periode: Maig 1994-Octubre 1995

Improvement of Higher Education and Training on Computational Engineering in Poland.
Presentat i aprovat en la convocatòria TEMPUS de 1994
Referència: S-JEP-07065-94
Periode: Setembre 1994-Agost 1997

Development and validation of educative software and courses for continuing active self-training in computer aided engineering (ASTRID).
Presentat i aprovat en la convocatòria Leonardo Da Vinci de 1995
Referència: E/95/2/1049/P/II.1.1.c/FPC
Periode: Desembre 1995-Desembre 97

Transatlantic University-Industry Cooperation Network (TUCANO).

Presentat i aprovat en la convocatòria ALFA de 1996

Periode: 1996-97

Numerical based medium level training on industrial friction problems (NUFRIC).

Presentat i aprovat en la convocatòria Leonardo Da Vinci de 2003

Referència: E/95/2/1049/P/II.1.1.c/FPC

Periode: Desembre 2003-Desembre 2006

A European Atelier for Engineering and Computational Sciences (EUA4X).

Presentat i aprovat en la convocatòria Marie Curie MSCF de 2004

Referència: MSCF-CT-2004-013336

Periode: Gener 2005-Desembre 2005

Soluciones especializadas de formación en multiplataforma inteligente (web-learning, mobile-learning y TV-learning) (3E-LEARNING).

Presentat i aprovat en la convocatòria de 2007

Referència: FIT-350100-2007-147

Periode: Gener 2007-Desembre 2009

1.6. Llibres docents

- **“Fundamentos de Resistencia de Materiales y Cálculo de Estructuras”**,
  M. Cervera y E. Blanco.
  E.T.S.E.C.C.P. de Barcelona, UPC. Novembre, 1992. ISBN: 84-604-4302-7

- **“Fundamentos de Resistencia de Materiales y Cálculo de Estructuras”**,
  segona edició, M. Cervera y E. Blanco.
  E.T.S.E.C.C.P. de Barcelona, UPC. Octubre, 1995. ISBN: 84-600-9231-3

- **“Fundamentos de Resistencia de Materiales y Cálculo de Estructuras”**
  M. Cervera y E. Blanco.
  Col.lecció Aula Politècnica / ETSECCPB. Edicions UPC. Setembre, 1999.
  ISBN: 84-8301-322-3

- **“Mecánica de Estructuras. Libro 1: Resistencia de Materiales”**
  M. Cervera y E. Blanco.
  Col.lecció Politex. Edicions UPC. Setembre, 2001. ISBN: 84-8301-518-8

- **“Mecánica de Estructuras. Libro 2: Métodos de Análisis”**
  M. Cervera y E. Blanco.
  Col.lecció Politex. Edicions UPC. Gener, 2002. ISBN: 84-8301-559-5

- **“Mecánica de Estructuras. Libro 1: Resistencia de Materiales”**, segona edición.
  M. Cervera y E. Blanco.
  Col.lecció Politex. Edicions UPC. Setembre, 2002. ISBN: 84-8301-622-2

- **“Mecánica de Estructuras. Libro 2: Métodos de Análisis”** segona edición.
  M. Cervera y E. Blanco.
  Col.lecció Politex. Edicions UPC. Gener, 2003. ISBN: 84-8301-635-4

- **“Análisis Matricial de Estructuras”**.
  E. Blanco, M. Cervera y B. Suárez.
  Edicions CIMNE. Gener, 2007. ISBN: 978-84-96736-07-5

- **“Estática de Estructuras”**,
  M. Chiumenti y M. Cervera.
  Edicions CIMNE. Juny, 2007. ISBN: 978-84-96736-20-7

1.7. Traducció de llibres

- Títol : El Método de los Elementos Finitos. Volumen 1: Formulación Básica.
  Autors : O. C. Zienkiewicz i R. L. Taylor
  Traductors : Miguel Cervera i Eugenio Oñate
  Editors : McGraw-Hill i CIMNE
  Edició : Quarta Edició, 1994. ISBN : 84-481-0177-4

- Títol : El Método de los Elementos Finitos.
  Volumen 2: Mecánica de Sólidos y Fluidos. Dinámica y No Linealidad.

Autors : O. C. Zienkiewicz i R. L. Taylor
Traductors : Miguel Cervera i Eugenio Oñate
Editors : McGraw-Hill i CIMNE
Edició : Quarta Edició, 1994. ISBN : 84-481-1760-3

- Títol : El Método de los Elementos Finitos. Volumen 1: Formulación Básica
  Autors : O. C. Zienkiewicz i R. L. Taylor
  Traductors : Miguel Cervera i Eugenio Oñate
  Editors : Butterworth-Heinemann i CIMNE
  Edició : Cinquena Edició, 2004. ISBN : 84-481-0177-4

- Títol : El Método de los Elementos Finitos. Volumen 2: Mecánica de Sólidos.
  Autors : O. C. Zienkiewicz i R. L. Taylor
  Traductors : Miguel Cervera i Eugenio Oñate
  Editors : Butterworth-Heinemann i CIMNE
  Edició : Cinquena Edició, 2004. ISBN : 84-481-1760-3

- Títol : El Método de los Elementos Finitos. Volumen 3: Mecánica de Fluidos.
  Autors : O. C. Zienkiewicz i R. L. Taylor
  Traductors : Miguel Cervera i Eugenio Oñate
  Editors : Butterworth-Heinemann i CIMNE
  Edició : Cinquena Edició, 2004. ISBN : 84-481-1760-3

- Títol : El Método de los Elementos Finitos. Volumen 1: Formulación Básica
  Autors : O. C. Zienkiewicz, R. L. Taylor i J.Z. Zhu
  Traductors : Gabriel Bugeda, Miguel Cervera i Eugenio Oñate
  Editors : CIMNE
  Edició : Sisena Edició, 2010. ISBN : 978-84-96736-71-9

- Títol : El Método de los Elementos Finitos. Volumen 2: Mecánica de Sólidos.
  Autors : O. C. Zienkiewicz i R. L. Taylor
  Traductors : Gabriel Bugeda, Miguel Cervera i Eugenio Oñate
  Editors : CIMNE
  Edició : Sisena Edició, 2010. ISBN : 978-84-96736-72-6

- Títol : El Método de los Elementos Finitos. Volumen 3: Mecánica de Fluidos.
  Autors : O. C. Zienkiewicz R. L. Taylor i P. Nithiarasu
  Traductors : Gabriel Bugeda, Miguel Cervera i Eugenio Oñate
  Editors : CIMNE
  Edició : Sisena Edició, 2010.ISBN : 978-84-96736-73-3

1.8. Ajuts a la docència

AGÈNCIA DE GESTIÓ D'AJUTS UNIVERSITARIS I DE RECERCA DE LA GENERALITAT DE CATALUNYA (AGAUR)

- Ajut pel finançament de projectes de millora de la qualitat docent en les universitats catalanes (MQD2008).
  Títol: Camins 2010: Nou pla docent de l'Escola de Camins.
  Gener 2008-Desembre 2009.

UNIVERSITAT POLITÈCNICA DE CATALUNYA

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
  Projecte: Elaboració llibre de "Mecànica d'Estructures".
  Setembre 2000-Setembre 2001.

- Ajut a Projectes de Coordinació del Personal Docent i de Recerca.
  Institut de Ciències de l'Educació.
  Projecte: Seguiment, valoració i explotació d'un nou model docent.
  Gener 2008-Desembre 2009.

E.T.S. D'ENGINYERS DE CAMINS, CANALS I PORTS DE BARCELONA

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
  Títol: Elaboración libro de "Mecánica de Estructuras".
  Setembre 2000-Setembre 2001.

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
  Títol: Elaboración libro de "Estática de Estructuras: Problemas resueltos".
  Setembre 2004-Setembre 2006.

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
  Títol: Elaboración libro de "Estática de Estructuras: Conceptos básicos y problemas resueltos".
  Gener 2008-Desembre 2008.

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
Títol: Elaboración libro de "Análisis Matricial de Estructuras".
Gener 2008-Desembre 2008.

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
  Títol: Elaboración de un soporte multimedia para la docencia de Resistencia de Materiales y Teoría de Estructuras.
  Gener 2008-Desembre 2009.

- Ajut a Projectes d'Innovació Educativa i Elaboració de Material Docent.
  Títol: Elaboración de dos libros de soporte a la docencia de Resistencia de Materiales y Teoría de Estructuras con problemas resueltos de la asignatura.
  Gener 2009-Desembre 2010.

- Ajut a Projectes per a la millora de la Docència.
  Títol: Soporte a la docencia de Resistencia de Materiales y Teoría de Estructuras (ITOP) y a su implantación en el EEES.
  Setembre 2010-Juliol 2011.

1.9. Càrrecs acadèmics

CÀRRECS ACADÈMICS (ETSECCPB)

- Càrrec : Sotsdirector d'Infrastructura i Patrimoni
  Periode : 1 de Març 1990-31 de Març 1991

- Càrrec : Sotsdirector en cap d'Estudis d'Enginyeria de Camins, Canals i Ports
  Periode : 1 d'Abril 1991-16 de Juny 1994

- Càrrec : Sotsdirector de Coordinació Acadèmica
  Periode : 17 de Juny 1994-15 de Setembre 1996

- Càrrec : Secretari Acadèmic
  Periode : 1 de Juny 1996-31 d'Octubre 1997

ALTRES CÀRRECS ACADÈMICS PER DESIGNACIÓ

- Membre de la Junta d'Escola en l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona en els periodes 1990-1991, 1992-1993, 1994-1995 i 1996-1997.

- Membre de la Comissió Permanent de l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona en els periodes 1990-1991, 1992-1993, 1994-1995 i 1996-1997.

- Membre de la Comissió d'Elaboració del Nou Pla d'Estudis de la titulació d'Enginyer de Camins, Canals i Ports de la ETSECCPB (1992-1994).

- Membre de la Comissió de Plans d'Estudis de la titulació de Graduat Superior en Enginyeria Geològica de la ETSECCPB i la Facultat de Geología de Barcelona (1992-1999).

- Membre de la Comissió d'Elaboració dels Nous Plans d'Estudis de les titulacions d'Enginyer Tècnic d'Obres Públiques, especialitat en Construccions Civils, en Transports i Serveis Urbans i en Hidrologia de la ETSECCPB (1993-1995).

- Membre de la Comissió d'Implantació i Seguiment de Plans d'Estudis de les titulacions d'Enginyer de Camins, Canals i Ports i Enginyer Tècnic d'Obres Públiques de la ETSECCPB. (1994-2002).

- President de la Comissió de Selecció i Avaluació de Professors i Investigadors del Departament de Resistència de Materials i Estructures en l'Enginyeria de la Universitat Politècnica de Catalunya (2001-2004).

- Vocal de la Comissió de Doctorat del Departament de Resistència de Materials i Estructures en la Enginyeria de la Universitat Politècnica de Catalunya (2001-2004).

- Coordinador de la línea de “Física i Estructures” de les titulacions de l’Escola Tècnica d’Enginyers de Camins, Canals i Ports de Barcelona 2001-2003, 2003-2005, 2005-2007, 2008-actualitat).

- President del Tribunal Qualificador de Proves de Conjunt (Homologació de Títols) de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona (2004-2006).

- President del Tribunal Qualificador de Proves d’Aptitut (Homologació de Títols) de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona (2006-actualitat).

- Membre de la Comissió Acadèmica del Màster en Enginyeria Civil de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona (2006-actualitat).

- Membre de la Comissió de Recerca i Postgrau de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona (2007-actualitat).

- Membre de la Comissió Tècnica de Revisió d’Exàmens de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona (2010-actualitat).

- Secretari de la Comissió d’Avaluació de Treball Final de Màster en Enginyeria Civil de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona (2010-actualitat).

CÀRRECS ACADÈMICS PER ELECCIÓ

- Membre electe de la Junta d’Escola, de l’Escola Tècnica Superior d’Enginyers de Camins, Canals i Ports de Barcelona en els periodes 1990-1991, 1992-1993, 1998-1999, 2000-2002, 2003-2005, 2006-2007, 2008- 2011 i 2012-2013. Membre nat en els periodes 1994-1995 i 1996-1997.

- Membre electe en la Comissió d'Avaluació Acadèmica del Departament de Resistència de Materials i Estructures en l'Enginyeria en els periodes 1993-1995, 1995-1997, 1997-1999 i 1999-2001.

- Membre electe del Claustre General de la Universitat Politècnica de Catalunya, com a representant del Departament de Resistència de Materials i Estructures en l'Enginyeria, en els periodes 1997-1999 i 1999-2001.

- Membre electe de la Comissió Permanent de l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona en els periodes 1998-1999, 2001-2002 i 2003-2005. Membre nat en els periodes 1990-1991, 1992-1993, 1994-1995 i 1996-1997.

- Membre electe de la Comissió d'Avaluació Acadèmica de l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona en els periodes 2000-2002, 2006-2007, 2008-2011 i 2011-2013.

- Cap de la Secció del Departament de Resistència de Materials i Estructures en l'Enginyeria en l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona en el periode 2001-2004.

- Membre electe de la Comissió de Selecció i Avaluació del Personal Docent i Investigador (CSAPDIU) de la Universitat Politècnica de Catalunya en el periode 2012-2015.

1.10. Càrrecs de gestió de recerca

- Càrrec : Coordinador de l'àmbit d`Enginyeria i Arquitectura'
  Organisme : AGAUR, Agència de Gestió d'Ajuts Universitaris i de Recerca de la Generalitat de Catalunya
  Periode : 1 de Setembre de 2010-actualitat

2. Resum de candidatura

L'activitat docent del **Prof. Miguel Cervera** s'inicia en el *Department of Civil Engineering, University College of Swansea, University of Wales* (Regne Unit), a on participa amb regularitat durant els cursos 1983–84, 1984–85 i 1985–86 en les activitats docents dels programes de grau i postgrau del departament, en qualitat de **teaching assistant** (professor ajudant), amb dedicació a temps complet.

Durant el curs 1987–1988 comença a impartir classes de les assignatures *Estructures I* i *Estructures II* de la titulació d'Enginyer de Camins, Canals i Ports de l'**Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona**, primer com a professor Titular Interí, i després com a Professor Titular d'Universitat, un cop guanyada la plaça de **Professor Titular d'Universitat** en l'Area de Coneixement " *Mecànica dels Medis Continus i Teoria d'Estructures*, en març de 1988.

A l'octubre de 1988 es fa càrrec, com a **professor responsable**, de l'assignatura *Resistència de Materials* de les titulacions d'**Enginyeria Tècnica d'Obres Públiques** de la ETSECCPB. Al 1997 es fa càrrec de l'assignatura *Estructures*, comú als nous Plans d'Estudis de les titulacions d'Enginyeria Tècnica d'Obres Públiques de la ETSECCPB.

Al 1998 es fa càrrec de l'assignatura *Aplicacions a l'Enginyeria Computacional* en el nou Pla d'Estudis de la titulació d'**Enginyer de Camins, Canals i Ports**.

Al gener del 1991 comença la seva participació com a professor en el **Curs de Master** *"Métodos Numéricos para Cálculo y Diseño en Ingeniería"*, curs integrat en la *Universidad Iberoamericana de Postgrado de la Oficina de Educación Iberoamericana (OEI)*.

Al febrer de 1994 comença la seva participació com a professor en els Cursos de Doctorat de la Universitat Politècnica de Catalunya integrada en els **Programes de Doctorat Interdepartamentals** en *Enginyeria Civil* i *Anàlisi Estructural*, ambdòs programes amb **Menció de Qualitat** de la *Secretaría de Estado de Universidades e Investigación*.

Al 1998 rep, junt amb Pere Roca i Eugenio Oñate, la *Menció Especial* al **"Premi Ciutat de Barcelona d'Investigació Tecnològica"** pel seu treball *"Modelització i anàlisi per ordinador de l'estructura de la Catedral de Barcelona"*, atorgat per l'Ajuntament de Barcelona.

Al juliol de 1999 guanya la plaça **Catedràtic d'Universitat** en Area de Coneixement de *Mecànica dels Medis Continus i Teoría d'Estructures*.

A partir de gener del 2000 participa com a professor en la versió a distància (a través d'**Internet**) del Curs de Màster *Métodos Numéricos para Cálculo y Diseño en Ingeniería* de la UPC. A partir de març de 2002 participa com a professor en la versió a distància (a través d'Internet) del Curs Introductori sobre *Cálculo de Estructuras por el Método de los Elementos Finitos* del CIMNE.

A partir de 2007 participa com a professor en els Cursos de **Màster Oficials** en *Enginyeria Civil*, *Enginyeria Estructural i de la Construcció* de l'Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona (UPC). També participa com a professor en el **Erasmus Mundus Master of Science Course in Computational Mechanics** i en el **Erasmus Mundus Advanced Master in Structural Analysis of Monuments and Historical Constructions**.

A l'abril del 2007 proposa a la Direcció de la ETSECCPB un pla d'**innovació de les metodologies docents de cara a la inminent implantació de l'Espai Europeu d'Ensenyament Superior**. El pla dóna lloc al **Projecte JANUS**, que durant el curs 2007-2008 s'implanta de forma experimental, en un dels grups de segon curs de les titulacions d'Enginyeria d'Obres Públiques. La valoració positiva d'aquesta experiència fa que en el curs 2008-2009 la nova metodologia s'extengui a la totalitat dels cursos d'Enginyeria d'Obres Públiques i s'implanti també en els primers cursos (Fase selectiva) d'Enginyeria de Camins, Canals i Ports i Enginyeria Geològica; en el curs 2009-2010 el procés s'extén també als segons cursos d'aquestes titulacions i en el curs 2010-2011 a **la totalitat dels cursos de les titulacions de l'Escola**. La metodologia va **duplicar el nombre d'alumnes que van superar amb èxit el bloc curricular corresponent, en tan sols tres anys** (del 30% al 60%). A l'assignatura *Estructures* s'assolí el 87.3% de ratio Alumnes Aprovats/Presentats i el 84,1% d'Aprovats/Matriculats amb 220 alumnes matriculats en dos grups (2007–2008).

Al setembre de 2011 comença la docència en el **Grau en Enginyeria de la Construcció**, com a professor responsable de les assignatures obligatòries comunes *Resistència de Materials* (segon curs) i *Estructures* (tercer curs) i l'assignatura obligatòria de l'Especialitat de Construccions Civils *Càlcul d'Estructures* (quart curs) de l'ETSECCPB.

En 1992 publica el llibre *"Fundamentos de Resistencia de Materiales y Cálculo de Estructuras", M. Cervera y E. Blanco*, que desde llavors s'ha emprat com a **text recomanat per l'ensenyament** de les corresponents assignatures de Teoria d'Estructures en al menys, **sis titulacions d'Enginyeria Tècnica i Superior** a Espanya, així com al menys **quatre titulacions d'Arquitectura Tècnica i Superior** a Espanya. En 2001 i 2002 publica els llibres *"Mecánica de Estructuras. Libro 1: Resistencia de Materiales", M. Cervera y E. Blanco* i *"Mecánica de Estructuras. Libro 2: Métodos de Análisis", M. Cervera y E. Blanco*. Desde llavors aquests llibres s'han emprat com a text recomanat per l'ensenyament de les corresponents assignatures de Teoria d'Estructures en al menys, **trenta-sis titulacions d'Enginyeria Tècnica i Superior** a Espanya, Portugal, Perú i Argentina, així com en al menys **quatre titulacions d'Arquitectura Tècnica i Superior** a Espanya. En 2007 publica el llibre *"Estática de Estructuras", M. Chiumenti y M. Cervera*, que desde llavors s'ha emprat com text recomanat per l'ensenyament de les corresponents assignatures de Teoria d'Estructures en al menys, **quatre titulacions d'Enginyeria Tècnica** a Espanya i Argentina. També ha co-traduit la quarta (2 volums) cinquena (3 volums) i sisena (3 volums) edicions del llibre *El Método de los Elementos Finitos* de O.C. Zienkiewicz i R. L. Taylor, obra de referència i d'extesa difussió en el seu àmbit.

Des del 1990 fins al 1996 és membre de l'**equip de Direcció de la ETSECCP** amb quatre Directors diferents, amb els càrrecs succesius de *Sotsdirector d'Infraestructura i Patrimoni, Sotsdirector en Cap d'Estudis d'Enginyeria de Camins, Canals i Ports, Sotsdirector de Coordinació Acadèmica i Secretari Acadèmic*, amb quatre Directors de l'Escola diferents. En aquest periode es van elaborar i implementar els Plans d'Estudi de les tres titulacions de l'Escola. Des de 2001 és **Coordinador de la línia** de "Física i Estructures" de totes les titulacions de l'ETSECCPB.

Al juny de 2010 és nomenat **Coordinador de l'àmbit** "d'Enginyeria i Arquitectura" d'**AGAUR**, l'Agència de Gestió d'Ajuts Universitaris i de Recerca de la Generalitat de Catalunya.

Al desembre de 2011 és escollit pel Claustre Universitari, a proposta del Rector, **membre de la Comissió de Selecció i Avaluació del Personal Docent i Investigador** (CSAPDIU) de la Universitat Politècnica de Catalunya, pel periode 2012–2015.

L'**activitat docent** desenvolupada durant els periodes 1984–88, 1989–93, 1994–98, 1999–2003 i 2004–2008 ha estat avaluada positivament per la corresponent Comissió Avaluadora de la Universitat Politècnica de Catalunya, així com per l'Agència per a la Qualitat del Sistema Universitari de Catalunya.

L'**activitat de recerca** desenvolupada en els periodes 1984–89, 1990–95, 1996–2001 i 2002–2007 ha estat avaluada positivament per la Subcomissió d'Enginyeria i Arquitectura de la *Comisión Nacional Evaluadora del Ministerio de Educación y Ciencia*, així com per la Subcomissió "d'Enginyeria i Arquitectura" de l'Agència per a la Qualitat del Sistema Universitari de Catalunya.

15è Premi a la Qualitat en la Docència Universitària

2012

Iniciativa Docent

Concepció, disseny, implementació i operació
de sistemes i productes del món real
de l'itinerari d'assignatures de projectes,
dirigit per Ramon Bragós

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Consell Social

Índex

1. Resum

Concepció, disseny, implementació i operació de l'itinerari d'assignatures de projectes en base a la iniciativa internacional CDIO és el nom que porta el projecte que presentem un grup de professors de l'ETSETB a la Modalitat 2 d'iniciativa docent, del Premi UPC a la Qualitat en la Docència Universitària del Consell Social.

El Projecte, endagat l'any 2008, i que actualment està finalitzant la seva primera fase, ha consistit en la incorporació a la nostra escola, dintre de la programació dels estudis de graus, de la metodologia CDIO (Conceive, Design, Implement, Operate).

L'origen del projecte sorgeix davant la necessitat d'adequar els nostres estudis al nou Espai Europeu d'Educació Superior. A l'igual que la resta de centres de la UPC, i degut al canvi legal, estàvem immersos en la proposta de nous plan d'estudis que s'havien de posar en funcionament abans de 2010. Per portar a terme aquest procés, l'equip directiu i tota la comunitat de l'ETSETB van iniciar l'elaboració del pla estratègic de l'escola, que incloia la cerca d'un nou model metodològic que donés resposta a les disfuncions que s'havien detectat de manera general en l'ambit de l'enginyeria en la inserció dels estudiants en l'àmbit laboral. Dentre els diferents models estudiats en la fase de **concepció (conceive)** del que havien de ser els nous graus, es va trobar com a més adequada la iniciativa internacional CDIO (www.cdio.org), liderada per l'MIT, i seguida per nombroses universitats tècniques de referència a tota Europa (KTH, Chalmers).

La iniciativa CDIO defineix eines i bones pràctiques per ajudar al disseny de plans d'estudis afegint a les competències especifiques de les matèries impartides d'altres més pròpies de l'exercici de l'enginyeria. Això facilita la incorporació de les competències genèriques, que inclouen aquelles comunes a tota la UPC i les pròpies del nostre centre. De tota manera, la tria en la fase de concepció d'aquesta iniciativa, no ha suposat un trasllat directe de les experiències d'altres universitats a la nostra, sinó que ha donat lloc, en la fase de **disseny (design)**, al desenvolupament d'un model propi, l'anomenat "model Barcelona", d'integració genèriques i les metodologies d'aprenentatge actiu en els estudis, mantenint el rigor i alt nivell d'adquisició de competències específiques propi

del nostre centre. Aquest model, acceptat i avalat internacionalment en les publicacions en congressos d'innovació docent, que també s'acompanyen com annexos, és el que es descriu en aquest document.

La **implementació (implement)** del nostre model, seguint el disseny previ, ha consistit en el desplegament d'un itinerari d'assignatures de projectes: Introducció a l'Enginyeria TIC, Projecte Bàsic d'Enginyeria i Projecte Avançat d'Enginyeria, a banda de Projecte Fi de Grau. Això significa una assignatura de projectes per cadascun dels segons quadrimestres de cada curs acadèmic, on es poden en pràctica amb diferents enfocament d'abast i profunditat tècnica, però sempre "hands-on", els aspectes de l'exercici professional de l'enginyeria que donin com a resultat un producte/servei/sistema, passant per totes les fases de **Concepció, Disseny, Implementació i Operació del mateix**.

La fase actual d'**Operació (operate)** en què es troba el projecte és la que fa escalable, després d'una primera experiència de tot l'itinerari amb 2 grups, la implantació del model a un volum important d'estudiants de tots els estudis de grau de l'ETSETB.

L'opinió actual dels estudiants que les cursen, així com dels estudiants de cursos superiors que ajuden al desplegament de les assignatures però que no han tingut oportunitat de cursar-les, com dels professors implicats en les mateixes (uns 20 actualment), és molt positiva.

En resum podem dir que majoritàriament s'han assolit els objectius plantejats inicialment amb el projecte de: i) incorporar l'aprenentatge per competències, ii) apropar els estudis de l'Escola a l'exercici professional de l'enginyeria iii) mantenir el nivell elevat, propi de la nostra escola, en l'adquisició de competències específiques iv) motivar l'alumnat a l'estudi en profunditat d'aquestes competències i v) augmentar el rendiment acadèmic dels nostres estudiants.

2. Descripció del projecte

2.1. Introducció

Els diferents marcs que van fixar les condicions de contorn del procés de confecció dels plans d'estudis adaptats a l'Espai Europeu d'Educació Superior (EEES o Bologna) feien èmfasi en l'adquisició de competències específiques i genèriques com a resultats de l'aprenentatge. Per adaptar aquest nou enfocament de la docència, l'ETSETB va endegar el gener de 2008 el procés d'elaboració d'un Pla Estratègic com a base per a la confecció dels Plans d'Estudis de Grau. Dins d'aquesta acció es va detectar la necessitat de trobar una metodologia que facilités la incorporació d'aquests conceptes. Es van estudiar tant els materials proposats per la Universitat Politècnica de Catalunya per tots els seus centres com els primers esborranys de les ordres ministerials de les enginyeries a Espanya i també els models docents utilitzats a diverses universitats d'Europa i dels Estats Units, així com diversos llistats de competències (ABET, Tuning, etc). Com a fruit d'aquest estudi es va identificar com a model més complet i estructurat el proposat per la iniciativa CDIO (www.CDIO .org).

La iniciativa CDIO és un marc educatiu innovador per a la formació d'enginyeres i enginyers del segle XXI. En el marc CDIO es proporciona als estudiants un ensenyament dels conceptes fonamentals de l'enginyeria en un context de **concepció, disseny, implementació i operació de sistemes i productes del món real**. CDIO va néixer l'any 2000 al MIT amb l'objectiu de reduir la distància existent entre el perfil de sortida dels seus enginyers i les necessitats de la indústria. Donat que aquest era un problema que afectava a tots els estudis d'enginyeria arreu del món, des del principi es va crear un grup de treball internacional, inicialment amb les universitats sueques de Chalmers i Linköping i el KTH. A partir de qüestionaris i entrevistes amb els agents externs (empreses, ex-estudiants i agències d'acreditació), l'any 2004 defineixen la llista de competències més exhaustiva que es coneix, el CDIO Syllabus i una llista de 12 estàndards. A continuació obren la seva iniciativa a la col·laboració internacional i actualment hi ha més de 80 institucions pertanyents a 25 països que són membres en diferents graus de la iniciativa.

L'ETSETB-UPC, després de comparar diversos models per a la definició dels plans d'estudis dels nous graus, identifica la iniciativa CDIO com el model més complet i coherent, hi entra en contacte al 4t congrés internacional a Gent l'any 2008 i presenta la seva candidatura com a centre col·laborador al 5è congrés internacional a Singapore l'any 2009, sent acceptada pel CDIO Council el juliol del 2009. El Juny del 2009 se celebra al Campus Nord un workshop amb els membres CDIO del centre i sud d'Europa amb la presència dels líders internacionals de la iniciativa. Des de llavors ha participat activament a diversos workshops i conferències, a la coordinació del grup d'Europa central i del sud i organitzarà el congrés internacional a Barcelona l'estiu del 2014.

La iniciativa CDIO defineix dues eines per ajudar a la confecció dels plans d'estudis, el Syllabus (conjunt de competències) i els estàndards (conjunt de bones pràctiques). El CDIO Syllabus recull les competències específiques, les genèriques i hi afegeix les més pròpies de l'enginyeria, associades al procés de disseny de productes i la realització de projectes i les agrupa en 4 àrees: 1) Coneixements científics i tècnics 2) Habilitats personals i professionals, 3) Habilitats interpersonals i 4) Capacitat per Concebre, Dissenyar, Implementar i Operar sistemes en el context de l'empresa i la societat.

El CDIO Syllabus està desenvolupat fins a un 3r nivell de concreció, amb descriptors per a cada una de les més de 70 competències. Actualment s'està definint la versió 2.0, en que es fa èmfasi en els aspectes de la emprenedoria i el lideratge. Els 12 estàndards de la iniciativa CDIO proporcionen la guia per a l'adaptació dels programes educatius i la seva avaluació. Proposen, a més de definir un currículum integrat amb les competències imbricades en les assignatures, inserir diverses assignatures de projectes (built-in experiences) en les quals, de manera natural, es desenvolupen diverses competències, tant personals, com interpersonals, com específiques de l'enginyeria. En particular, es recomana dur a terme una assignatura específica el primer curs on es realitzi una introducció a l'enginyeria i un primer projecte a fi que l'estudiant pugui identificar el context en el qual es desenvoluparà la seva formació i enfocar correctament la resta d'assignatures del grau. Es tracta, en definitiva, de considerar les competències genèriques com el context de l'aprenentatge de l'enginyeria i no el seu contingut, que seguirà constituït per les competències específiques de les distintes matèries. Per tal de facilitar aquest procés, es va decidir incloure a l'estructura dels plans d'estudis un conjunt d'assignatures de projectes, situades al segon quadrimestre de cada curs.

2.2. Objectius

L'objectiu principal d'aquest projecte ha estat dotar als plans d'estudis de grau d'una estructura i adoptar una metodologia que i) permetin incorporar l'aprenentatge per competències de manera natural, ii) incloguin activitats que apropin els estudis de l'Escola a l'exercici professional de l'enginyeria iii) mantinguin el nivell elevat, propi de la nostra escola, en l'adquisició de competències específiques iv) motivin l'alumnat a l'estudi en profunditat d'aquestes competències i v) augmentin el rendiment acadèmic dels nostres estudiants.

Per aconseguir-ho, s'ha dissenyat una estructura mixta que implementa els estàndards de la iniciativa CDIO:

- S'assigna a cada assignatura les competències específiques que corresponen a la matèria i dues de les competències genèriques. La incidència de la inserció d'activitats formatives associades a les competències genèriques ha de ser baixa i s'ha de fer de la forma més natural possible.
- Es creen un conjunt d'assignatures de projectes repartides al llarg del grau que han de tenir un triple impacte:
    - **Consolidar** l'aprenentatge de les competències específiques i genèriques de les assignatures que es duen a terme en paral·lel i de les anteriors.
    - **Motivar** l'estudiantat en el treball al voltant de les competències específiques i genèriques de les assignatures que es duran a terme posteriorment.
    - Treballar en un **context pròxim al de l'exercici professional de l'enginyeria** i, com a conseqüència, oferir un marc per a desenvolupar de manera natural la major part de les competències genèriques, en especial les que són difícils d'implementar en assignatures convencionals.

Aquests són els objectius de les assignatures de projecte, el disseny i primers resultats de les quals es presenta al Premi a la Qualitat en la Docència Universitària 2012.

Es proposa doncs un model d'aprenentatge propi, presentat dins de la iniciativa CDIO com a "model Barcelona", en el que l'aprenentatge basat en projectes està orientat al context (context-oriented PBL) i en el que els continguts disciplinaris estan assegurats per assignatures més convencionals i reforçats per les assignatures de projectes.

El nostre enfocament es contraposa al model d’aprenentatge basat en projectes orientat a continguts (contents-oriented PBL), en el que la docència en una determinada matèria es fa íntegrament mitjançant un projecte. La raó d’escollir el PBL orientat a context en comptes de l’orientat a continguts és la voluntat de mantenir un nivell alt d’aprenentatge de les diferents competències específiques, cosa en la que PBL orientat a continguts ha demostrat no tenir tan bons resultats dins de l’entorn CDIO.

2.3. l’itinerari d’assignatures de projectes als plans d’estudis de grau de l’ETSETB

Hi ha quatre assignatures de projectes, situades al quadrimestre de primavera de cada un dels quatre cursos del grau (figura 1). La darrera és el Treball de Fi de Grau (24 crèdits) i té una regulació específica. Es duu a terme individualment dins d’un departament o empresa, en molts casos en un altre país. Les tres primeres són el curs d’Introducció a l’Enginyeria TIC (ENTIC), de 6 crèdits, el Projecte Bàsic d’Enginyeria (PBE) també de 6 crèdits i el Projecte Avançat d’Enginyeria (PAE), de 12 crèdits. La taula 1 resumeix les seves característiques.

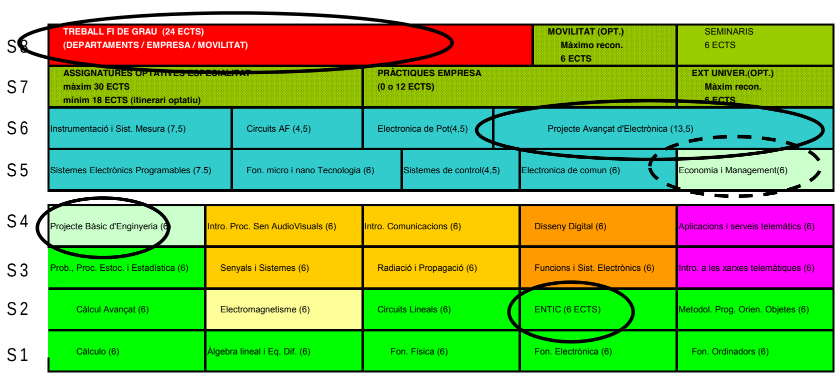

Figura 1. Situació de les assignatures de projecte al pla d’estudis d’un grau, a l’exemple el d’Enginyeria de Sistemes Electrònics.

Subject	Term	Credits (hours)	Main topics and characteristics	Group size
Introduction to ICT Engineering	2	6 (150)	System view Basic economics Project management Seminars Guided project	4
Basic Engineering Project	4	6 (150)	Seminars (< 20%) Open basic engineering project Focus on design and implementation.	4-6
Advanced Engineering Project	6	12 (300)	Seminars (< 20%) Advanced and complex engineering project Different topic per group Focus on conception, innovation and entrepreneurship	9-12
Thesis project	8	24 (600)	Individual (by Spanish law) Performed in a company or research group, on campus or in an international exchange.	1

Taula 1. Resum de les característiques de les quatre assignatures de l'itinerari de projectes

L'amplada de l'enfocament i el grau d'aprofundiment de les tres assignatures varia a mida que avancen els cursos, tal com es pot veure a la figura 2. ENTIC dona una visió ampla del procés de desenvolupament d'un producte, des de les necessitats del client fins al mercat, però amb poca profunditat. Pretén donar als estudiants una visió global del procés per a què identifiquin la necessitat de les diferents disciplines que es trobaran al llarg del grau i les implicacions econòmiques de cada pas d'un desenvolupament tecnològic. A PBE, s'aprofundeix en el disseny, implementació i verificació d'un bloc concret d'un sistema, definit a partir de les seves especificacions, té un enfocament més estret, purament tècnic. A PAE es recupera l'amplada de la visió, anant des de l'especificació fins al pla de negoci, però dissenyant i implementant cada una de les parts en que s'ha subdividit el sistema i integrant-les.

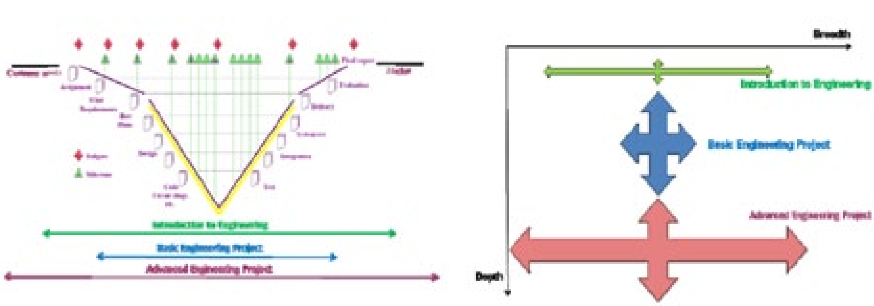

Figura 2. Amplada de l'enfocament i grau d'aprofundiment de les tres assignatures de projecte

Passem a descriure-les amb més detall:

<u>Curs d'introducció a l'Enginyeria TIC (ENTIC</u>), a primer curs, 6 crèdits, equips de treball de 3-4 estudiants. Té una funció de bastida: identificar tasques, competències i marc de treball de l'enginyeria. Motivar per a l'aprenentatge de les altres assignatures. Formació específica en continguts d'economia i empresa. S'articula en tres itineraris paral·lels connectats a través d'un cas d'estudi comú.

Itinerari 1: Conceptes bàsics d'economia i empresa (2 hores / setmana) Aspectes organitzatius i econòmics del desenvolupament de productes i serveis TIC: Introducció a la gestió de projectes, models de negoci TIC, costos i inversions, eines de generació d'idees, màrqueting, implicacions socials. Plantejament d'una idea de negoci a nivell bàsic sobre el cas d'estudi.

Itinerari 2: Visió de sistema (1 hora / setmana). 4 a 6 sessions en què el professor exposa als estudiants l'estructura de sistema i els principals aspectes tecnològics, econòmics i socials de diversos productes TIC complexos. Posteriorment, es fa un seminari sobre recerca d'informació (BRGF) i un altre sobre comunicació oral i escrita. A continuació els estudiants preparen i presenten en públic altres productes o serveis TIC diferents dels exposats pel professor i són avaluats pels professors i els seus companys .

Itinerari 3: Experiència de disseny implementació (2 hores / setmana) Disseny i implementació d'un sistema complex. Projecte parcialment guiat en el qual equips de 3-4 estudiants realitzen la implementació de la part mecànica d'un sistema predissenyat (per exemple un robot) i dissenyen i implementen un o diversos subsistemes TIC sobre aquesta plataforma (mesura, control, comunicacions, ...). Aquest últim itinerari consolida els aprenentatges dels altres dos.

En els primers tres anys que portem, aquest projecte s'ha anomenat ICT-iNeo i es fa sobre variants d'un vehicle subaquàtic (o Remotely Operated underwater Vehicle - ROV) que transmet mesures de paràmetres de l'aigua i de navegació del propio vehicle a una estació remota, consistent en un PC. El projecte actual s'ha basat en la plataforma SeaPerch del MIT Sea Grant Program, per al que l'ETSETB ha establert un conveni amb aquesta institució (s'adjunta). La plataforma és un ROV molt simple. La part electro-mecànica del robot es construeix amb tubs de PVC, motors, cables i interruptors i els estudiants la conclouen en les primeres 3 sessions de laboratori, afavorint la consolidació dels equips de treball i l'aprenentatge dels conceptes bàsics de gestió de tasques. A la figura 3 es pot veure el SeaPerch bàsic, amb l'estructura, els motors i els interruptors de control i, a la dreta, la prova d'immersió al llac del rectorat.

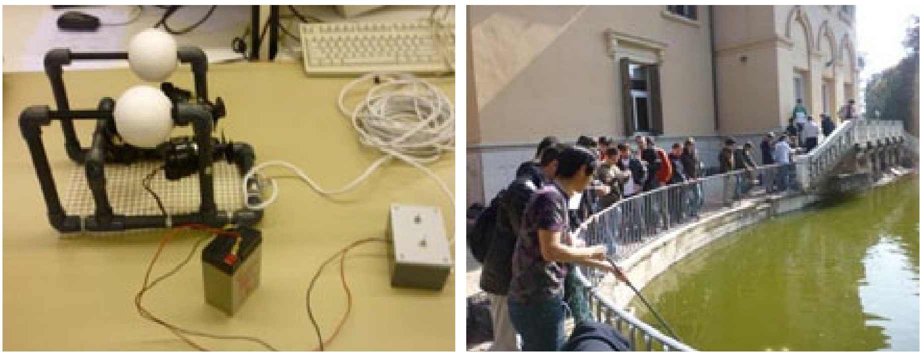

Figura 3. SeaPerch bàsic, format per una estructura de PVC i 3 motors de contínua controlats mitjançant interruptors remots connectats a través d'un cable. A la dreta, prova d'immersió.

Aquesta part electro-mecànica és accessible fins i tot per a estudiants de secundària i al MIT la fan servir per a activitats d'extensió universitària amb els instituts. L'última hora de la tercera sessió, es fa una immersió col · lectiva (figura 3 dreta) que, a part de resultar motivadora i divertida, estableix una fita clara, per al lliurament del qual els estudiants s'esforcen notablement.

Passades aquestes tres setmanes, els estudiants s'enfronten al repte de dissenyar i construir un determinat payload per al ROV que canvia cada any. Els projectes previstos inclouen el mesurament i registre de paràmetres de l'aigua (temperatura, profunditat, absorció de llum, conductivitat, ...), sistemes de comunicacions (RF, òptiques, acústiques), control (gestió dels motors, control de navegació) i protocols de comunicacions i xarxa. En els quadrimestres en què s'ha implementat, s'ha dut a terme la mesura de la pressió com indicador de profunditat, la temperatura de l'aigua en funció d'aquesta profunditat, la mesura d'absorció de llum en funció també de la profunditat, la reconstrucció de la trajectòria del vehicle a partir de la detecció dels seus girs i la mesura de la seva inclinació. En funció de la capacitat de cada grup, se'ls demana que afegeixin prestacions addicionals al robot. Apart del sistema electromecànic del ROV i de la presentació d'una idea de negoci bàsica basada en un dispositiu similar a aquest, el projecte cobreix el disseny i implementació d'un sistema TIC complex, ja que inclou la cadena de mesura completa: sensor, amplificadors, adquisició, digitalització, transmissió, processament i representació de les mesures. A la figura 4 es pot veure un dels ROV amb les caixes estanques que inclouen els sensors i circuits que mesuren i envien les dades a un ordinador extern. En aquest cas, i com a aportació extra, els estudiants hi van incorporar una càmera.

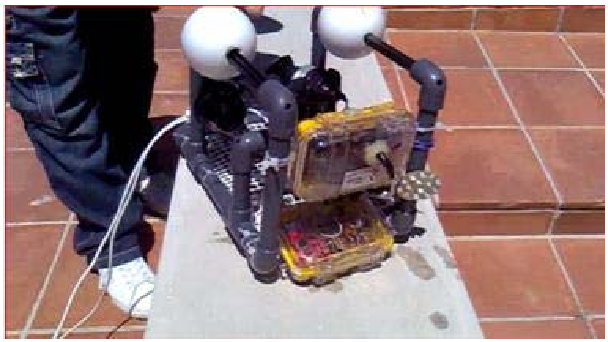

Figura 4. SeaPerch amb les caixes estanques que inclouen els sensors i circuits que mesuren i envien les dades a un ordinador extern.

Projecte Bàsic d'Enginyeria (PBE) a segon curs, 6 crèdits, equips de treball de 4 estudiants. Dos dels crèdits s'utilitzen per impartir un curs sobre projectes regulats en infrastructures de telecomunicacions i els 4 restants pel projecte de disseny i implementació d'un bloc d'un sistema TIC complex, amb coneixement de la estructura del sistema complet i de les especificacions de tots els blocs. S'hi dedica un laboratori de 3 hores a la setmana més el corresponent treball autònom.

Es parteix d'uns requeriments de client i es fa una descomposició del sistema en blocs i la traducció de requeriments en especificacions de cada bloc en sessions participatives amb els estudiants, guiades pel professor. Tots els estudiants han de conèixer l'estructura del conjunt i les especificacions de les interfícies entre els blocs, però els equips de treball (4 estudiants) de cada grau (grups de 5 equips) es concentren en un dels components del sistema. Tot i estar el segon curs en el bloc comú, l'estructura dels grups de laboratori permet que els estudiants puguin escollir el subsistema d'acord amb el grau en què s'han matriculat i en què s'especialitzaran en el tercer i quart curs (electrònica, telemàtica, sistemes audiovisuals o sistemes de telecomunicació). S'ha intentat trobar un equilibri entre la metodologia PBL orientada a continguts i el projecte orientat a context, que quadra més amb el model docent de l'Escola, en què les assignatures de projectes donen suport a les altres i no les substitueixen. Així, l'estructura del curs inclou tres sessions inicials orientades a dotar de continguts disciplinaris relacionats amb el tema del projecte utilitzant parcialment la metodologia del puzle. En aquest punt, el bloc queda totalment especificat i documentat en el document de requeriments i especificacions. Les següents 10 sessions es dediquen al disseny, creació de prototips, validació dels blocs, integració i caracterització del subsistema. Els estudiants organitzen el projecte en paquets de treball, que plasmen en el document de Pla de Projecte. Tota la documentació està en anglès. Es duen a terme dues revisions del disseny (preliminary and critical design review) en les setmanes 4 i 8 respectivament i una final la setmana 12.

El producte triat el primer any ha estat un sistema de distribució d'àudio mitjançant streaming en un entorn universitari (Campus Nord). Es tracta que els estudiants siguin capaços de reproduir amb alta qualitat d'audio, mitjançant un altaveu actiu, el senyal provinent d'una emissió en streaming, via ràdio, en qualsevol lloc del Campus (figura 5). Els blocs en què se subdivideix el sistema (figura 5 dreta) es reparteixen entre els equips agrupats per graus. Els d'Enginyeria Electrònica dissenyen, implementen i caracteritzen un amplificador d'audio de classe D, els de Sistemes Audiovisuals desenvolupen eines software per caracteritzar el sistema i millorar la qualitat del so, els de Sistemes de Telecomunicació dissenyen l'enllaç radio i les antenes i els d'Enginyeria Telemàtica el protocol d'streaming via wifi. Els del grau generalista es poden apuntar a qualsevol dels grups.

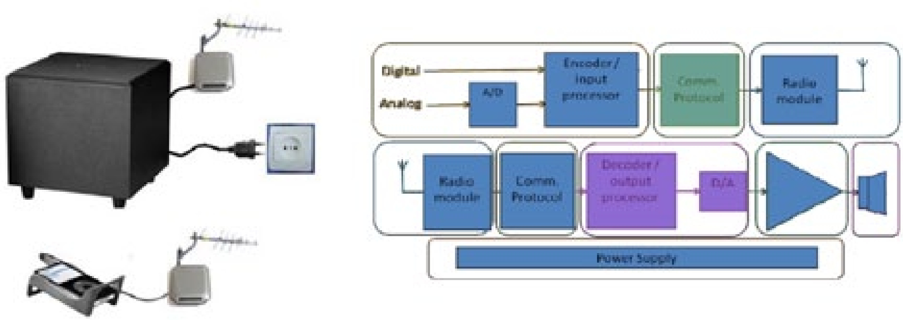

Figura 5. Definició del producte: component d'un sistema d'àudio que reprodueix el so d'una font d'àudio digital rebuda a través d'un enllaç radio. A la dreta, descomposició en blocs que dissenyen i implementen els diferents grups.

Projecte Avançat d'Enginyeria (PAE) a tercer curs, 12 crèdits ECTS als quals s'afegeixen 1,5 crèdits addicionals de continguts de matemàtiques coherents amb el projecte. Equips de treball de 9-12 estudiants. La temàtica del projecte és específica del grau escollit tot i que es preveu que hi pugui haver projectes transversals.

Es parteix de la identificació d'un producte o servei TIC que porta associada una oportunitat de negoci. El sistema ha de ser prou complex com per necessitar desglossar-lo en 3-4 parts i que 3-4 subgrups de treball de 2-3 estudiants, realitzin la especificació, disseny, implementació i verificació de les parts i la seva integració i verificació del conjunt. A part d'ha de desenvolupar un pla d'empresa basat en el producte. Els estudiants s'han de coordinar internament a nivel de subgrup i també a nivell de tot l'equip.

Hi ha un itinerari de seminaris de 2 hores a la setmana en el que els estudiants participen en seminaris de gestió de projectes, confecció d'un pla d'empresa, treball en equip d'alt rendiment, system thinking, creative thinking, propietat industrial, recerca en bases de dades de patents i d'informació empresarial, ... També tenen tutories sobre la confecció del pla d'empresa i sobre aspectes matemàtics avançats relacionats amb el projecte. El projecte té una forta càrrega de treball autònom (15 h/setmana) i 6 hores/setmana de disponibilitat de laboratori amb professor/supervisor. Els grups de treball tenen una reunió setmanal amb presència dels professors/supervisors. Hi ha tres fites al llarg del projecte (Preliminary design review a la setmana 3, Critical design review a la setmana 7 i Final design review a la setmana 12). Com en totes les altres assignatures de projectes, tota la documentació es fa en anglès i, en aquest cas, també la presentació final i diversos dels seminaris. Els projectes s'exposen públicament mitjançant un pòster i també es redacta una patent. Aquest primer any en què es fa PAE amb els grups d'Enginyeria Electrònica i d'Enginyeria de Sistemes Audiovisuals, els primers estan dissenyant i implementant els subsistemes electrònics d'un picosatèl·lit tipus Cubesat (figura 6, panells solars i font d'alimentació, computador d'abord, sistema de control d'actitut, sistema de comunicacions i càrregues útils diverses) i els segons un sistema de caracterització acústica de sales amb identificació de la posició mitjançant un GPS acústic, de forma que es pot donar un mapa de la resposta acústica de la sala.

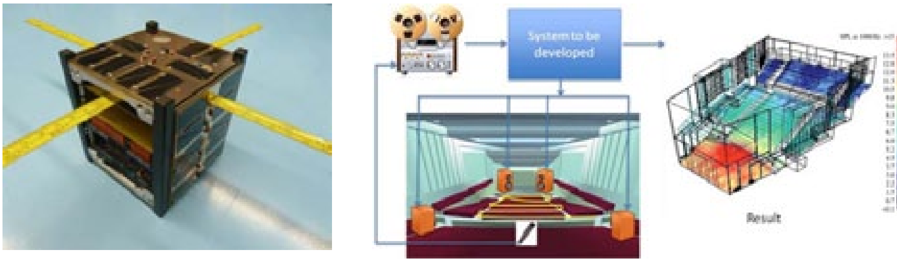

Figura 6. Temes dels projectes del curs 2011-2012. Picosatèl·lit Cubesat i sistema de mapeig de la resposta acústica de sales.

El curs PAE constitueixen una experiència d'aprenentatge d'efecte culminant i integrador, que resulta en múltiples reforços creuats de competències, (a) d'una banda els diferents continguts disciplinaris del pla d'estudis hi intervenen i es posen en pràctica al tractar-se de sistemes complexos d'enginyeria amb multiplicitat de subsistemes (b) d'altra banda, l'alumnat ha de revisar, en el context del projecte, els continguts adquirits en les assignatures convencionals, tot reforçant-los (c) el projecte s'inicia amb un seminari temàtic que presenta el context del projecte i que, atesa la transversalitat i complexitat del sistemes abordats, requereix revisar i entrelligar els coneixements de les diferents assignatures del grau. D'altra banda, aquest tipus de experiències *capstone* està consolidada en d'altres països, i es planteja per tant que en un futur, dins el consorci CDIO, els estudiants de grau l'ETSETB puguin participar en competicions i cooperacions internacionals de projectes.

2.4.Metodologia de treball

El disseny dels nous plans d'estudis s'ha plantejat com un projecte, incloent doncs les fases de concepció, disseny, implementació i operació. Pel que fa a la concepció, tal com ja s'ha dit a la introducció, l'ETSETB va partir de l'elaboració d'un Pla Estratègic com a marc per a la confecció dels Plans d'Estudis de Grau i es va identificar la iniciativa CDIO com el model més complet. En aquesta fase hi va participar l'equip directiu de l'ESTETB, en especial Elisa Sayrol, Ramon Bragós, Eduard Alarcón i Josep Pegueroles.

Pel que fa al **disseny**, s'utilitzen els estàndards i el syllabus de la iniciativa CDIO, a més dels requeriments de la UPC i del Ministeri per establir les especificacions. Es dissenya un conjunt de matèries i una estructura integrada que inclou el repartiment de les competències al conjunt de matèries i un itinerari d'assignatures de projecte. Es creen comissions de grau que desglossen les matèries en assignatures i es nomenen coordinadors que elaboren els objectius i les activitats formatives de les assignatures. Pel que fa a l'itinerari d'assignatures de projecte, objecte d'aquesta memòria, es crea un grup de treball format per 4 professors de l'ETSETB dels departaments d'Enginyeria Electrònica (Eduard Alarcón i Ramon Bragós), Teoria del Senyal i Comunicacions (Adriano Camps), i Enginyeria Telemàtica (Josep Pegueroles), que elaboren l'estructura de l'assignatura d'Introducció a l'Enginyeria i de les dues assignatures de projecte del segon i tercer curs i inicien l'itinerari.

La **implementació** del que podríem considerar els prototipus de les assignatures, es va poder fer amb dos grups pilot gràcies a que el curs 2009-2010 es van iniciar només els graus d'Enginyeria de Sistemes Audiovisuals i d'Enginyeria de Sistemes Electrònics amb 40 estudiants cada un. D'aquests estudiants, 60 estaven en disposició de cursar ENTIC el quadrimestre de primavera i es van fer dos grups, un per cada grau, amb dos professors a cada un. L'itinerari d'economia i empresa de l'assignatura el duen a terme des de llavors quatre professors del departament d'Organització d'Empreses (Carolina Consolación, Olga Pons, Joan Sardà i Jaume Mussons), que imparteixen els temes d'acord amb el seu camp d'expertesa. També des de l'inici es compta amb la col·laboració de l'equip de la Biblioteca Rector Gabriel Ferrater, dirigit per Miquel Codina, que imparteix seminaris sobre l'ús eficaç dels recursos d'informació i la correcta citació de les fonts. Les modalitats docents que s'utilitzen són actives, l'assignatura no té examen final, i es basen en l'assoliment de fites que s'avaluen amb rúbriques, l'entrega de documents i la presentació pública de resultats. Tota la documentació escrita està en anglès i s'utilitza profusament Atenea com a plataforma per a l'intercanvi d'informació i recollida dels encàrrecs lliurables.

La primera cohort que arriba al quadrimestre de primavera de segon i pot cursar el Projecte Bàsic d'Enginyeria és de 24 estudiants, combinats d'Electrònica i Sistemes Audiovisuals. En aquest cas, dels blocs mostrats a l'apartat anterior, es desenvolupen l'amplificador d'àudio i la seva caracterització. S'incorpora a l'equip el professor Albert Oliveras, del departament de Teoria del Senyal i Comunicacions. Com s'ha dit, aquest projecte és fonamentalment tècnic. A més dels resultats d'equip (60%), es desenvolupen un conjunt d'activitats amb resultats lliurables de caràcter individual i es fan dos controls breus sobre el coneixement individual del treball conjunt que permeten modular la qualificació atorgada al grup. Un 30% de la nota s'obté en funció del grau d'assoliment dels requeriments del sistema i un 10% en funció de la coherència entre les avaluacions individuals dels membres de cada equip, per promoure l'esforç de cadascú per obtenir el millor resultat conjunt.

La primera cohort que arriba al quadrimestre de primavera de tercer i pot cursar el Projecte Avançat d'Enginyeria és de 27 estudiants, 18 de Sistemes Audiovisuals i 9 d'Electrònica. S'agrupen en tres equips de treball de 9 membres que afronten la realització de tres projectes, sota la supervisió dels mateixos 5 professors que els han tingut a les dues assignatures de projectes anteriors. En aquest cas, el paper dels professors, a part de definir els projectes, lliurar els requeriments i preveure les necessitats, és més de supervisor que d'assessor. Durant una hora cada setmana es fa una reunió de seguiment amb cada grup en la que els professors adopten el rol de clients i en tres moments del curs, el rol de revisors de la documentació sobre l'evolució del projecte i els seus resultats. La qualificació de grup surt de l'avaluació del treball en aquestes fites, modulada (40%) per la informació sobre el treball individual que es recull en els *progress reports* i les reunions de seguiment. Els professors del departament d'organització d'empreses, juntament amb els supervisors i alguns professors i professionals externs imparteixen els seminaris (2 hores cada setmana), que s'han enumerat a l'apartat anterior.

Fins ara s'ha descrit com s'ha dut a terme la implementació del que anomenem "el front d'ona", és a dir, el disseny i la primera implementació de cada una de les assignatures. La fase d'**Operació** del projecte comença quan les assignatures entren en explotació i s'han d'impartir a quantitats més grans d'estudiants i per part de professors diferents als que han dissenyat les assignatures i les seves metodologies. Cal formar el pool de professors que, de forma combinada amb altres assignatures convencionals, impartiran les assignatures de projectes, i que, en règim permanent, hauria de ser d'uns 40 professors. Es pretén que tinguin experiència a la indústria o participin en empreses spin-off o bé que tinguin una experiència de transferència de tecnologia rellevant o, com a mínim, aportin experiència prèvia en modalitats formatives actives. Aprofitant el fet que la majoria dels professors inicialment motivats veuen molt atractiu participar al projecte avançat del tercer any, s'ha creat el que anomenem l'itinerari formatiu dels professors, que assegura la coherència en la metodologia utilitzada als tres projectes: per ser supervisor del projecte

avançat s'ha d'haver passat abans per Introducció a l'Enginyeria i per Projecte Bàsic, i el primer cop que un professor fa cada una d'aquestes assignatures ho fa al costat d'un altre que ja l'ha fet. A part d'això, es fan sessions de formació pels nous professors abans de començar cada quadrimestre i reunions de seguiment. Al final de cada curs es recullen les observacions sobre els punts febles i es proposen accions per corregir-los.
Els estudiants que segueixen la cohort que ha entrat una tardor, fan les assignatures de projectes a la primavera de cada any, en que els grups són més nombrosos. Per exemple, a la primavera ENTIC té al voltant de 240 estudiants (60 equips de treball) i la imparteixen 12 professors (3 de nous aquest curs) més els 4 d'organització d'empreses. A la tardor, en canvi, cursen ENTIC o PBE els estudiants que han repetit algunes assignatures del quadrimestre anterior i s'han retardat. Això fa que hi hagi menys grups d'estudiants (uns 60 a ENTIC, per exemple). S'aprofita aquest quadrimestre per introduir professors nous en tàndem amb els altres d'una forma més pausada. En total, ara hi ha 20 professors (15 TU i 5 CU) participant en la part tècnica d'alguna de les assignatures de projectes, i 5 d'ells ho fan en més d'una simultàniament ja que n'estan formant d'altres. A més hi ha els 4 professors d'Organització d'Empreses, la participació de personal de la BRGF i la col·laboració puntual d'altres professors en algunes sessions de seminaris.

2.5.Avaluació de l'experiència

A hores d'ara, i a la espera de la sortida de les primeres cohorts, podem parlar d'un rendiment acadèmic molt alt (entre el 82% i el 94% a ENTIC, incloent els abandonaments, 100% a PBE) i d'una motivació i grau d'autonomia creixent que fa molt satisfactòria la experiència de fer de supervisor a PAE. Un altre indicador és el fet que el nombre de professors, de solvència contrastada, que s'interessen per entrar a l'itinerari és més que suficient per mantenir el creixement necessari per arribar al règim permanent d'aquí a dos anys. Encara un altre aspecte del que s'esperen obtenir beneficis més enllà de l'activitat acadèmica és l'augment de la relació i el coneixement entre professors de diferents departaments, als llocs on fa temps que ho fan, ha repercutit en les activitats de recerca.

En general de la valoració de professors i estudiants és molt positiva i la valoració preliminar que en fan els membres del consell assessor d'empresa i els professionals als que hem explicat el projecte també. Els estudiants del segon cicle anterior que tenen beques de col·laboració i ens ajuden en les assignatures, poden comparar els dos plans d'estudi i valoren molt bé l'experiència, amb un cert ressentiment per no haver fet ells aquestes assignatures, tot i que el fet de donar suport al seu desenvolupament també els dona un complement a la seva formació.

L'avaluació real d'aquesta experiència la tindrem quan les primeres promocions d'estudiants dels nous graus arribin a la indústria. La valoració dels agents externs, els mateixos que han donat lloc a la necessitat de la reforma i que han validat el procés, serà la única realment significativa. En els centres de la iniciativa CDIO on fa més anys que ho fan (Chalmers porta 10 anys), els resultats en aquest sentit són espectaculars.

D'altra banda, una forma més acadèmica de valorar l'experiència és a partir de les comunicacions a congrés i les publicacions:

- R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas, J. O'callaghan, J. Pegueroles, L. Prat, G. Sáez, J.Sardà, E. Sayrol. "Proceso de inserción de competencias genéricas en los nuevos planes de estudios de grado de la ETSETB-UPC de acuerdo con el modelo CDIO" TAEE'2010, Madrid, Abril 2010.

- Ramon Bragós, Eduard Alarcón, Adriano Camps, Josep Pegueroles, Joan Sardà, Elisa Sayrol "Conceiving and Designing an "Introduction to Engineering" Course Within the New Curricula at Telecom BCN, UPC Barcelona" 2010 International CDIO Conference, Montréal, June 2010.

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En el moment de tancar aquest document hi ha una comunicació acceptada al congrés TAEE'2012 que se celebrarà a Vigo el mes de juny i dues més a la International CDIO Conference que tindrà lloc a Brisbane el proper mes de juliol.

Per concloure, i a l'espera de validar els resultats quan els graduats portin un o dos anys a la indústria, voldríem destacar la incidència que aquest disseny ha tingut en els plans d'estudis de grau de l'ETSETB, una escola de tall clàssic en la que creiem sincerament que aquesta acció ha actuat de revulsiu. També el fet que, partint d'una posició rellevant pel que fa a la excel·lència en la recerca i el nivell dels titulats, però modesta pel que fa a la innovació educativa, hem trobat una molt bona acceptació del model proposat en fòrums internacionals i ens hem integrat de manera ràpida i efectiva en la iniciativa CDIO, tenint interlocució directa amb els líders, agafant un paper dominant al sud d'Europa i aconseguint portar la conferència internacional de 2014 a Barcelona.

Ramon Bragós, en representació del col·lectiu de professors que han engegat aquest projecte.

Barcelona, 7 de març de 2012

3. Telecom BCN

CONCEIVING AND DESIGNING AN "INTRODUCTION TO ENGINEERING" COURSE WITHIN THE NEW CURRICULA AT TELECOM BCN, UPC BARCELONA

Ramon Bragós

Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Eduard Alarcón

Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Adriano Camps

Telecom BCN, Signal Theory and Communications department, UPC, Barcelona, Spain

Josep Pegueroles

Telecom BCN, Telematics department, UPC, Barcelona, Spain

Joan Sardà

Telecom BCN, Management department, UPC, Barcelona, Spain

Elisa Sayrol

Telecom BCN Dean, Signal Theory and Communications department, UPC, Barcelona, Spain

I. ABSTRACT

This paper describes a course devoted to "Introduction to ICT Engineering" which, building upon initial restrictions and specifications, has been conceived, designed and implemented at Telecom BCN, UPC BarcelonaTech. This is the first of a set of four design-build courses distributed along the new degrees curricula structure, which have been designed using the CDIO Syllabus and Standards as Engineering Education paradigm. The course is organized in three intertwingled tracks, covering (a) the systems view of complex ICT systems; (b) the basic economics and management concepts of ICT products and services, including project management, and (c) the lab practice of these methods, together with the acquisition of generic skills by the realization of a design-build project (focused upon an undewater robot with emphasis in electronic communication aspects) in student teams. The design and implementation of the lab system ICT-related subsystems displays problems whose advanced solutions will be discovered in the subsequent courses within the curricula. The course is currently running as a pilot course with two small groups (30+30 students) before fully deploying it next year to all the new degrees.

II. KEYWORDS

Introduction to Engineering, Design-build experiences, 1st year course, curriculum design

III. INTRODUCTION

At Telecom BCN, the Electrical and Telecom Engineering School of the Technical University of Catalonia (UPC), we started three years ago the design of the new curricula within the European Higher Education Area framework (Bologna process). Five new bachelor degrees (4 year-long) have been designed. Two of them (Audiovisual Systems Engineering and Electronics Engineering) have already started their courses this academic year (2009-2010). The remaining three degrees (Communication Systems Engineering, Networks, and Telecom Science and Technology) will start in September 2010.

The adaptation to the Bologna process allowed us to perform an in-depth reorganization, so that CDIO was chosen as paradigm for new curricula design. The learning outcomes were identified; the skills and abilities list was defined and developed by matching our University standards with the CDIO Syllabus[1]. Finally, the curricula structure was established. We used a mixed approximation to integrate CDIO skills into the curricula: On the one hand, the skills pathways were defined by involving all courses. Every course may contribute to the learning of several skills at a given level (basic, medium, advanced) and should actively contribute to develop and assess two of them. On the other hand, four specific project-centered courses have been scattered along the curricula, at the second semester of each academic year. They all include design-build activities and put emphasis on the CDIO Syllabus fourth group of skills. Table 1 shows their main characteristics.

Table 1
Project subjects along the curriculum

Subject	Semester	Credits (hours)	Main topics and characteristics	Group size
Introduction to Engineering	2	6 (150)	System view Basic economics Project management Seminars Guided project	4
Basic Engineering Project	4	6 (150)	Seminars (< 20%) Open basic engineering project Focus on design and implementation.	6
Advanced Engineering Project	6	12 (300)	Seminars (< 20%) Advanced and complex engineering project Different topic per group Focus on conception, innovation and entrepreneurship	9-12
Thesis project	8	24 (600)	Individual (by Spanish law) Performed in a company or research group, on campus or in an international exchange.	1

We are currently in the first year of the implementation of two new engineering degrees (40 + 40 students) and the following academic year, the remaining and more massive three degrees (up to 260 students) will start. The entry year is selective, thus the students should pass a given number of subjects from the first semester to be allowed to attend the second semester and should pass all subjects form the first year to be allowed to attend the second year. According to this, near 30 students per degree (27+29) have been allowed to attend the "Introduction to engineering" course in the second semester of the first year. The two class groups constitute the first cohort that acts as pilot experience in the implantation of the new methodology, given that the first two years are common to all degrees.

In the first semester they have completed algebra, calculus, physics, and introductory courses to electronics and computers. In the second semester they are studying advanced calculus, electromagnetism, circuits theory, object-oriented programming and introduction to engineering. This last subject was placed at the second half due to regulations (coherence in the first year structure between engineering degrees of the same area). This fact is considered positive because the students which attend this subject have already demonstrated a given performance and have also acquired a set of knowledge and skills that allow coping with basic design-build projects.

IV. THE “INTRODUCTION TO ENGINEERING” SUBJECT

Initial Specifications and Restrictions

This course is formally called “Introduction to ICT Engineering” (ICT stands for “Information and Communication Technologies”) and its design has taken into account several initial specifications and restrictions:

- As stated in the 4th CDIO standard [1], it should provide the framework for engineering practice in product and system building, and introduce essential personal and interpersonal skills.
- Being at the first year, and due to our University regulations, it should include basic economics topics.
- According to the recommendation of our strategic plan committee and steering committee, it should introduce the system view in complex ICT engineering products, processes and services. This aspect agrees with CDIO Syllabus point 2.3.
- Also according to regulations (homogeneous structure of first year courses), the subject should have 6 ECTS credits (ECTS, European Credit Transfer System), which corresponds to a student workload of 150 hours along 15 weeks. 66 of these hours are carried out in a classroom or laboratory with lecturer support, whilst the remaining 84 hours correspond to autonomous work, both individual and group work.
  The students have 3 regular sessions per week, two of them of 2 hours and one of 1 hour, plus the autonomous work.

Course Learning Outcomes

The main course goal is: “To understand the engineering context and acquire motivation through the exposure to complex system building”. As a secondary goal, the course should help to integrate the basic knowledge the students have already learnt and, specially, trigger the curiosity for the concepts they will learn in the subsequent disciplinary courses.

As main learning outcomes, after attending this course, the students should be able of:

- Have a systemic view of ICT products and services
- Describe the main concepts and perform basic calculations about the economics of design, production and commercialisation of ICT products and services
- Carry out the basic steps on project planning, development and documentation

They should also have acquired the learning outcomes of several generic skills. Our University has defined a set of seven mandatory skills and our School has added three extra skills and defined the outcomes of all of them according to CDIO Syllabus and with three depth levels (basic, medium, advanced). They are displayed in table 2. This course, as all other project courses, helps to improve the vast majority of the transversal or generic skills, but in the organization of the skill pathways, the Introduction to Engineering course has the explicit request to provide and assess four of them at 1st (basic) level. Those which are more difficult to assess in conventional courses have been chosen.

Table 2
Generic skills stressed and assessed in this course

#	Generic Skill	Exposed	Stressed	Assessed
1	Innovation and entrepreneurship	X	X	X
2	Societal and environmental context	X	X	X
3	Communication in a foreign language (English)	X	X	
4	Oral and written communication	X	X	X
5	Teamwork	X	X	
6	Survey of information resources	X	X	
7	Autonomous learning	X		
8	Ability to identify, formulate and solve engineering problems	X		
9	Ability to Conceive, Design, Implement and Operate complex systems in the ICT context	X	X	X
10	Experimental behaviour and ability to manage instruments	X		

Course Design

In order to achieve these requirements, we organized the subject in three parallel tracks, connected between them through a common topic. This is coherent with the three regular sessions per week they have. The three tracks cover the three main learning outcomes: 1- System View, 2-Basic Economics, 3-Project management and development through a hands-on project.

Track 1: System View

Regular sessions of 1 hour/week.

Goals/learning outcomes. The students should be able to:

- Describe the system structure and main characteristics and identify the involved technologies of several complex ICT products and services presented by the faculties and other students.

- Identify the features and business models which are common to the different ICT systems.
- Find information about an ICT product or service, other than those used as examples. Summarize it, clearly identifying the following aspects: Need of the product, business model, system structure, involved technologies, societal and environmental implications.
- Plan and perform a 15 minutes oral presentation devoted to the product or service assigned and answer correctly the questions raised from the audience.

Track 1 structure: 5-6 sessions in which the lecturer exposes the students to face the system structure and main technological and economical aspects of several complex ICT products (Internet, cell phone, GPS, …). All presentations include the following aspects: Background, need of the product, system structure, involved technologies, abridged history, business model and societal implications. The presentations are also used to introduce concepts that link with other disciplinary subjects. Subsequently, a seminar on oral and written communication follows, and then, several additional sessions in which the students perform cooperative work preparing and presenting additional ICT products or services. The student's presentations are 15 min long and are performed by two people (out of a 4 person team). A session allocates 3 presentations.

Track 2: Basic Economics of design, production and commercialisation of ICT products and services

Regular sessions of 2 hours/week.

Goals/learning outcomes. The students should be able to describe the main concepts and perform basic calculations on the economics of production and commercialisation of ICT products and services. Roughly, the goal of this track is to impress in the mind of the students that the design and production of every product has a cost and requires an initial investment that expects a return. In the third year, they have a more formal Economics and Management 6 ECTS subject and they also have seminars spread in the project courses.

Track 2 structure: Regular sessions in which a specific lecturer from the Management and Business Department gives a lecture or set of lectures about each of the following topics:

- Introduction to project management
- Idea generation tools: SWOT and Brainstorming
- ICT Business models
- Cost determination
- Profitability of investments
- Marketing

The main deliverable of this track is a business idea that should be developed by teams at a very basic level and presented in public. The business idea should be closely related with the common topic chosen in the course and which is also used in track 3 (hands-on project). Presentations take place in the last week of the course and should include the following items: To identify a need, to propose a business idea that covers this need and to evaluate costs, investment and benefit (at a very basic level). The final presentation is performed by the two remaining team members who did not present in track 1.

Track 3: Design-Implement experience

Regular sessions of 2 hours/week.

Goals/learning outcomes. The students should be able to:

- Perform the basic steps on project planning, development and documentation, following a partially guided design, and complementing it with small and open design-implementation activities.
- Acquire the learning outcomes corresponding to the basic level of the generic skills specified in Table 2.

Track 3 structure: This track is performed from the first day in a laboratory in teams of 4 students. Although the engineering degrees in our School are ICT related, we consider that the topic around which the project and the track 2 business idea is to be built, should have moving parts to boost the first-year students motivation. Then, the project will be typically built around a robot or a vehicle. The implementation of the mechanical parts following a guided design can take 3-4 weeks. It would not need other machining skills than those that the students had acquired in the Technology subjects of High School. This activity would promote the team consolidation and the distribution of tasks. Given that the concepts about project management are lectured in parallel in the track 2, the first 3 weeks of the project are performed in an intuitive basis with very little guidance. After that, the students are asked to think about which tasks had been performed, which team members were devoted to each task and which tasks had been or could have been performed in parallel. After that, they document in a task list and in a Gantt diagram the already carried out part and are asked to plan the remaining part of the project. This second part is a small but complex ICT system, complex in the sense that it includes several heterogeneous subsystems. Typically it would be the integration of one or several sensors, conditioning circuits, an acquisition system, a communication link and a program that reads and performs a basic processing of the acquired data. They should take decisions on how to configure and connect the systems and design a few small parts (conditioning circuits or data processing code). Of course, they start from a set of client requirements from which they should write a product specification, a project plan, progress reports and a final report. The documentation procedure is a simplified version of the LIPS method [2].

Additionally, several out-of-track 1 or 2 hour seminars are spread in the course, with the following topics: sustainability and social commitment, information gathering, and intellectual and industrial property. The last two topics are presented by staff of the University Library.

Course Implementation

Common Topic for tracks 2 and 3

The chosen common topic for the following 5 years is the remotely operated underwater vehicle (ROV) and its applications. Being the Track 3 a partially guided project, the economic aspects are very simple and do not allow to exploit the concepts explained in track 2. To overcome this problem, the students should prepare a business idea based on a product or service (pollution measurement, archaeological search, cleaning, security, …) built around a ROV and present it in public. This common topic acts as a liaison between tracks. We call this project ICT-iNeo, which is a play on words related with “ictineo”, a submersible designed and built in Barcelona by Narcis Monturiol in 1859 [3] A good alternative for the mechanical part of the project, in the Track 3, is the SeaPerch platform [4], a simple remotely operated underwater vehicle (ROV) conceived and developed at the MIT Sea Grant College Program. This part of the underwater robot can be built using PVC pipes in the first 3-4 sessions, favoring the consolidation of the work teams. Afterwards the students face the challenge of designing and building a specific ROV payload that changes every year. The foreseen projects include measurement and data logging of water parameters (temperature, depth, light absorbance, conductivity, …), communication (Wired, RF, optical, acoustical), control (efficient motor driving, computer control of navigation) and networks. This first introducing year we have requested our students to design and build a system able to acquire water temperature and depth (through pressure) pairs along the trajectory of the underwater vehicle, with a distance limit of 10 m and a depth limit of 3 m. The system should store the measured data and also transmit them using an additional wire pair in the tether that is used to control the 3 vehicle motors.

The students have acquired the basic knowledge in electronics to understand the pressure and temperature sensors behavior. At the “Circuits Theory” subject, which is lectured in parallel to our subject, they work with basic Operational Amplifiers based circuits that allow them to perform a partially guided design of the amplifiers. They connect the output of both circuits to a small datalogger (Logomatic v2) from SparkFun [5]. The datalogger acquisition routine is already programmed. They can configure the system to choose the measured entries and the acquisition rate. Additionally to the data storage in a micro-SD card, already present in the datalogger, we have modified the program to send the acquired data in a basic serial format. This allows the students to send the data through a wired link and discover the need of a physical (bit rate and levels) and logical (format, headers, …) protocol. They can easily manipulate the parameters of this protocol through program parameters. Lots of concepts which will be formally studied in subsequent subjects are introduced here: sensitivity, gain, dynamic range, coupling of dynamic ranges in acquisition chains, A/D conversion, errors, calibration, data transmission, protocols, …). The working hypothesis is that the students should pay more attention to the formal explanations of mathematical models and technological solutions of these concepts after having realized their need in a real system they have built.

At the moment of closing this paper, the students have already set-up the measurement and acquisition of two variables (P and T) and are working in two fronts: building the final version of the circuit in a prototype board together with the datalogger, and understanding the communications protocol. In 3 more weeks they should be able to perform a contest in a swimming pool to demonstrate and compare the performance of their systems.

Track 1: System View

The topics chosen to illustrate the system view of complex ICT systems in the first 6 sessions of this year are the following (a sounding sentence announces each topic):

- Cochlear implant: "Hear this! The tinniest ever bionic implant"
- Cell Phone: "Ubiquitous communications crystallize: Silicon chips for cellular phones"
- Undersea communications: "The big battle against the sea"
- The Voyager: "The Farthest Communication Ever Made"
- Internet: "The way Alexander the Great got connected"
- Earth Observation Satellites: "Taking the Pulse to the Planet"

In each session, additionally to the mentioned aspects presented for each topic, a few concepts are introduced. For instance, in the "Cochlear Implant" topic, the concepts of decibel and the frequency decomposition of a signal; in the presentation about the Voyager, the decrease of electromagnetic (EM) field with distance and the signal to noise ratio. Two days before each presentation, a web page or document related with the topic is made available in the moodle-based LMS system of the University (Atenea digital campus). This information is complementary but not substitutive of the presentation. For instance, for the "Cochlear Implant" topic, they should read a web page about the physiology of the ear and for the "Cell Phone" topic, an abridged report from the European Commission about the effects of EM fields on human beings. To ensure that the students read these materials and attend the presentation, a previous and a post questionnaire are placed in the digital campus. They should answer them in 20 min and they have two attempts. The result is a very small part of the assessment, which is mainly given by their own presentations, but if they do not perform the questionnaires, the mark of this track is reduced. During the presentations, we have used the TurningPoint voting system to dynamize the sessions. At the end of the 6 sessions performed by the lecturers, they choose a topic for its own presentation from a list proposed by the faculties. Then, three weeks are devoted to present seminars about oral and written communication and about intellectual and industrial property. This gap gives time to the students to prepare their 15 minutes presentations which they will perform the last three weeks at a rate of three groups per session. The synchronization of the three tracks can be seen in the table 3. From the originally available 15 weeks, due to the holiday days and the fact that this subject does not have final exam, 13 sessions are available for each track.

Table 3
Course calendar

<table>
<tr><td>Week</td><td colspan="2">Track 2
2 h/week
Management and Business</td><td>Track 1
1h/week
ICT System View</td><td>Track 3
2/h week (split group)
ICT-iNeo Project</td></tr>
<tr><td>1</td><td>Course introduction</td><td>Information gathering</td><td>“Cochlear Implant”</td><td rowspan="12">ICT-iNeo project</td></tr>
<tr><td>2</td><td colspan="2">Introduction to project management</td><td>“Cell phone”</td></tr>
<tr><td>3</td><td colspan="2">SWOT and Brainstorming</td><td>“Undersea phone communication”</td></tr>
<tr><td>4</td><td colspan="2" rowspan="2">Project management</td><td>“The Voyager”</td></tr>
<tr><td>5</td><td>“Internet”</td></tr>
<tr><td>6</td><td colspan="2" rowspan="2">ICT Business models</td><td>“Earth observation satellites”</td></tr>
<tr><td>7</td><td rowspan="2">Seminar on oral and written communication</td></tr>
<tr><td>8</td><td colspan="2">Cost determination</td></tr>
<tr><td>9</td><td colspan="2">Profitability of investments</td><td>Seminar on intellectual and industrial property</td></tr>
<tr><td>10</td><td colspan="2">Marketing</td><td rowspan="3">Students presentations on system view</td></tr>
<tr><td>11</td><td colspan="2" rowspan="2">Sustainability and social commitment</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td><td colspan="4">Presentations on business ideas</td></tr>
</table>

Resources

As mentioned in the introduction, this first year implementation is being performed with a reduced set of students, two groups of around 30 people, in a pilot experience. The track 2 (economics) is being carried out by a set of 4 lecturers from the Economics and Management Department. Each one lectures the lessons corresponding to their specialty (project management, costs, marketing, ...). The book “Product Design and Development”, from Karl Ulrich and Steven Eppinger [6] is used to prepare this part.

Four more faculties teach the tracks 1 and 3, two of them in each class group, and both are simultaneously in the classroom. This structure has been built in order to train a team of people that could assume the second implementation phase of the subject with the 250 expected students the next year. Each actual lecturer will form a pair with a new one next year in one or two class groups. Every lecturer who plans to teach in the higher project courses (2nd and 3d year) should also be or have been involved in the "Introduction to Engineering" course, in order to keep the coherence in the methodology. With this structure, we plan to have a set of around 40 lecturers teaching in the project subjects in 4 years.

Six granted teaching assistants help us with the preparation and testing of the project alternatives (2 of them) and supporting the students in the laboratory (2 TAs in each class group). The electronics engineering laboratories already have a modular structure that allows the work in teams. We have added a small mechanical workshop that complements them and allows making the mechanical parts of the projects. The current Campus improvement program includes building new spaces for teamwork and a larger mechanical workshop, as well as spaces to store the student's projects. We have got specific funds from the University to buy the materials and tools necessary to carry out the projects. Most of these materials are reusable.

V. CONCLUSIONS

From initial restrictions and specifications, an "Introduction to Engineering" course has been conceived, designed and implemented at Telecom BCN, UPC, Barcelona. This is one of four design-build subjects that the students will perform according to the new degrees curricula, which have been designed using the CDIO Syllabus and Standards as Engineering Education paradigm.

The course is organized in three tracks, covering the system view of complex ICT systems with presentations performed both by the faculties and the students; the basic economics and management concepts of ICT products and services, together with project management concepts, and the practice of these methods, together with the acquisition of generic skills by the realization of a design-build project in teams of 4 students.

This project allows starting with a simple mechanical device which is appealing and even fun. The student's performance does not depend upon their previous knowledge but upon their ability to follow a plan. The design of the system ICT-related subsystems displays problems whose advanced solutions will be discovered in the following courses of the curriculum. The whole project allows putting in practice the project management concepts presented in track 2 and which will be reinforced in the following 3 project subjects, whose complexity and degrees of freedom grow year by year.
The course is being carried out (operated) with two small groups (30+30 students) in a pilot experience before applying it to all the new degrees next year. At the time of closing this paper, there are still 4 weeks to finish this term. Next June we will be able to complement the description by presenting the final results of the course first-round implementation and operation during this semester.

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VII. BIOGRAPHICAL INFORMATION

Ramon Bragós is associate professor at the Electronics Engineering Department of Technical University of Catalonia (UPC). His current research focuses on electrical impedance spectroscopy applications in biomedical engineering. He lectures at Telecom BCN, where he is the Associate Dean of Academic Innovation.
Eduard Alarcón is associate professor at the Electronics Engineering Department of UPC. His current research includes signal and energy processing on silicon. He lectures at

Telecom BCN, where he has been Associate Dean of International Affairs and is now USA-Liaison Adjunct to the Dean.

Adriano Camps is full professor at the Signal Theory and Communications department of UPC. His current research focuses in microwave remote sensing, with special emphasis in microwave radiometry by aperture synthesis techniques and remote sensing using signals of opportunity. He lectures at Telecom BCN.

Josep Pegueroles is associate professor at the Telematics department of UPC. His current research focuses security for multimedia networked services and secure group communications. He teaches at Telecom BCN where he is the Secretary of the Managing Team.

Joan Sardà is Lecturer at the Management department of UPC. His expertise field is cost analysis. He lectures at Telecom BCN, where he is the Associate Dean for Quality management.

Elisa Sayrol is associate professor at the Signal Theory and Communications department of UPC. Her current research focuses on image and video analysis as well as image and video watermarking. She lectures at Telecom BCN where she is the Dean.

VIII. CORRESPONDING AUTHOR

Ramon Bragos
UPC – Technical University of Catalonia
Campus Nord, B3. c/ Jordi Girona 1-3
08034 Barcelona, Spain
sotsdirlabs@etsetb.upc.edu

DESIGN OF THE BASIC ENGINEERING PROJECT SUBJECT FOR THE SECOND YEAR OF ELECTRICAL ENGINEERING AT TELECOM BCN

Ramon Bragós

Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Eduard Alarcón

Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Josep Pegueroles

Telecom BCN, Telematics department, UPC, Barcelona, Spain

Adriano Camps

Telecom BCN, Signal Theory and Communications department, UPC, Barcelona, Spain

Albert Oliveras

Telecom BCN, Signal Theory and Communications department, UPC, Barcelona, Spain

Miguel García-Hernández

Telecom BCN, Electronics Engineering department, UPC, Barcelona, Spain

Elisa Sayrol

Telecom BCN Dean, Signal Theory and Communications dept, UPC, Barcelona, Spain

I. ABSTRACT

The Basic Engineering Project is a second year subject which represents the second of four steps in the design-implement subjects path of the Telecom BCN curricula. The first one is included into the Introduction to Engineering subject and the last one is the degree Thesis. While the first and third year projects have a wide scope (from client specification to business idea), the second year project emphasizes on the technical design, implementation and characterization of a given block from its specifications but understanding the whole system concept and has a higher technical difficulty. A complex ICT system is split in blocks. All students should know the block structure but a given work team will only develop one of the system blocks. The structure of laboratory groups allows that students could select the block according to the major they will choose the following year (electronics, networks, audiovisual systems and communications). The course structure design includes three initial sessions oriented to provide disciplinary contents related with the project topic using the puzzle methodology. Then the block to be

designed is fully specified and documented in the Requirements Specification document. The following 10 sessions are devoted to the design, prototyping and validation of the chosen system block. Their schedule is determined by the time plan and work package organisation that the work teams prepare and write in the Project Plan document. The preliminary and critical design reviews are performed during two progress meetings in the 7^{th} and 11^{th} week. This first year of implementation, the product to be designed, that has been divided in blocks is an in-home audio system component. Given that the course is running this first year with a pilot group of 24 students, only the amplifier and preequalizer blocks have been designed and built by the students.

II. KEYWORDS

Design-build subject, Electronic Engineering, Audiovisual Engineering, Project-based Learning.

III. INTRODUCTION: THE DESIGN-BUILD SUBJECTS PATH AT TELECOM-BCN

Five new bachelor degrees (4 year-long) have started this 2010-2011 academic year at Telecom BCN, the Electrical and Telecom Engineering School of the Technical University of Catalonia (UPC). Two of them (Audiovisual Systems Engineering and Electronics Engineering) already started the last academic year as pilot courses and the remaining three degrees (Communication Systems Engineering, Networks, and Telecom Science and Technology) are now running the second semester.

According to the CDIO Standards, we designed the curricula structure using a mixed approach to integrate CDIO skills into the curricula: On the one hand, the skills pathways were defined by involving all courses. Every course may contribute to the learning of several skills at a given level (basic, medium, advanced) and should actively contribute to develop and assess two of them. On the other hand, four specific project-centered courses have been scattered along the curricula, at the second semester of each academic year. They all include design-build activities and put emphasis on the CDIO Syllabus fourth group of skills.

Table 1 shows their main characteristics.

Table 1
Project subjects along the curriculum

Subject	Semester	Credits (hours)	Main topics and characteristics	Group size
Introduction to Engineering	2	6 (150)	System view Basic economics Project management Seminars Partially guided project (2.4 ECTS)	4
Basic Engineering Project	4	6 (150)	Regulatory aspects of ICT (2 ECTS) Open basic engineering project (4 ECTS) Focus on design and implementation of a given block of a complex system	4-6
Advanced Engineering Project	6	12 (300)	Seminars (< 20%) Whole design and implementation of an advanced and complex engineering project Different topic per group Focus on conception, innovation and entrepreneurship	9-12
Thesis project	8	24 (600)	Individual (by Spanish law) Performed in a company or research group, on campus or in an international exchange.	1

Last academic year, 56 students from the two pilot degrees followed the *Introduction to Engineering* subject. The experience was reported in the 2010 CDIO Conference [1]. This year, 240 students are running it. Meanwhile, 24 students from the first cohort are taking the pilot course of the second design-build subject, the *Basic Engineering Project*.

The scope balance of the design-build subjects of the first three years is similar to that reported in [2], although the implementation of the first year project is quite different. The scopes of the first and third projects are wide while the second one is narrower. The depth, of course, increases each year. In the next figure, the scope of the three project subjects is displayed under the LIPS project cycle representation [3]:

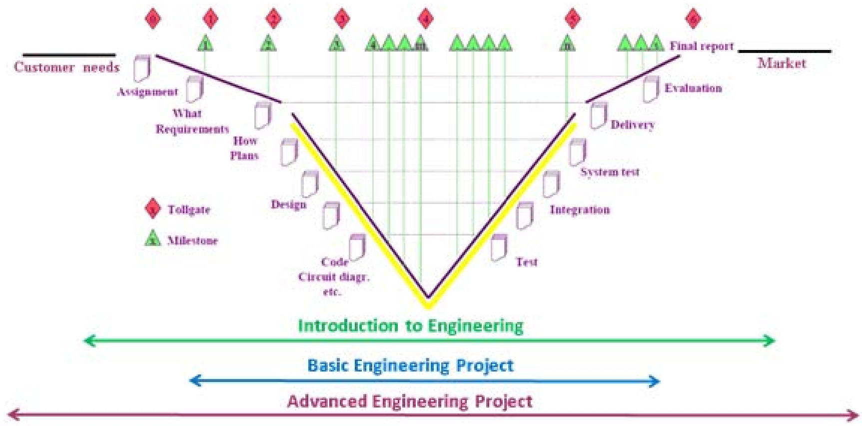

Figure 1. Scope of the three first design-build subject projects represented below the LIPS project cycle representation (adapted from [3]).

The project included in the Introduction to Engineering subject is partially guided and has low complexity, but has a broad scope, given that the students start from a system-level client specifications, they design parts of the system, build the whole system and should define a business idea based on a similar device. On the other hand, the second year project (Basic Engineering Project) has a higher technical difficulty and emphasizes the modular structure of complex ICT systems, although a work team will only develop one of the system blocks. The product is defined by the client (faculties) and also the block breakdown is given. The student teams should design and implement only a given block from specifications but knowing the whole system structure and the interfaces between blocks. The final result is delivered to the company internal client (again the faculties). In the third year project (Advanced Engineering Project), larger work groups would develop a whole system, including its business plan. They should conceive the product, define the project breakdown structure and work packages, distribute them between the sub-teams, design and implement the sub-systems, integrate them and define a business plan based on the product. That is, to take the broad scope of the first project together with the depth of the second and the business and management concepts learnt in a specific subject which is located in the first half of the third year. The Advanced Engineering Project subject has not yet been implemented. It will be done in the second half of the 2011-2012 academic year.

IV. THE BASIC ENGINEERING PROJECT SUBJECT

Course structure

Two of the six ECTS credits are used to learn the contents and practical aspects on the regulation of telecommunications, which is required for the professional ICT engineering practitioners in Spain. The Basic Engineering Project is performed in the remaining 4 ECTS credits (3 hours/week in the lab + 4 hours/week of autonomous work). It can be argued that a reasonable way to arrange this double function of the subject would have been to include the regulatory aspects in the projects. This is true, but this solution drives to the need of performing strict telecommunication facilities projects with all students, while the adopted solution allows us to choose a wider range of topics. With the selected way, if a given set of students choose an advanced project on telecom facilities, they would learn more about regulatory contents, but all students have received the minimum mandatory training.

There is a constraint due to the structure of our curricula: the students of electrical engineering are attending their second year, which is common to all of them, but they are going to split in four majors in the third year: electronics, audiovisual systems, networks and telecommunication systems (there is an additional degree, which has a wider scope, Telecom Science and Technology). Then, the students' interests can be slightly different. A whole system would include aspects from all these specialities, but not a given block. Then, there is a trade-off between the depth and breadth of the design given the limited time schedule (4 ECTS credits). To solve this compromise, we have designed a course structure where the students will be allowed to choose which part of the system would develop. A given system (figure 2) is divided in four blocks including aspects of hardware development, communications, network protocols and audio/image/video signal processing. Given that the second year students are mixed in class groups, we should

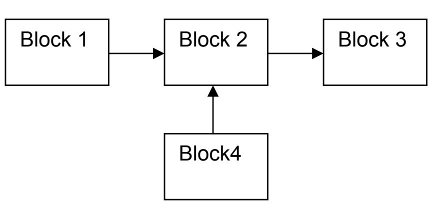

Figure 2: System block diagram

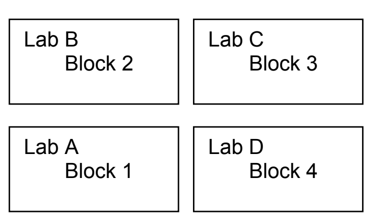

Figure 3: Simultaneous labs structure

give simultaneous labs with support of lecturers from different departments (figure 3) Students can be grouped together to make the project according to their specialty although they are mixed up in class. Two class groups (60-80 students) would give enough diversity to fill the four sub-projects. Variations in the technology used to implement each block can drive to different projects built around an initial proposal, which allows amortizing the effort made by the faculties when designing the case study and use it along 2-4 semesters.

Course goals and learning outcomes

Course goals:

- Consolidation and improvement of the learning outcomes of previous and simultaneous courses
- Enhancement of the CDIO skills at medium level (mainly Design and Implementation)
- Acquisition of generic skills at medium level (see table 2)

Learning outcomes:

- Project management and documentation skills
- Specific disciplinary knowledge about the project topic
- Practical design and implementation skills
- System and circuit level simulation and characterization
- Measurement strategies
- Electronic components selection and circuit building
- Generic skills learning outcomes (assigned and defined in the degree syllabus)

Table 2
Generic skills (medium level) stressed and assessed in this course

#	Generic Skill	Exposed	Stressed	Assessed
1	Innovation and entrepreneurship	X	X	X
2	Societal and environmental context	X	X	X
3	Communication in a foreign language (English)	X	X	
4	Oral and written communication	X	X	X
5	Teamwork	X	X	
6	Survey of information resources	X	X	
7	Autonomous learning	X		
8	Ability to identify, formulate and solve engineering problems	X		
9	Ability to Conceive, Design, Implement and Operate complex systems in the ICT context	X	X	X
10	Experimental behaviour and ability to manage instruments	X	X	

Course design

The students are grouped in teams of 4-6 (depending on the project complexity) and sign a team constitution agreement in which they define their role and commit to have a common ambition of reaching a given mark (pass, good, outstanding). A major concern we have had in the course design is the interpretation and application of the PBL methods to the course design. Leaving apart the classical concept of the "project subject" in the Spanish Engineering Schools, centred in the formal aspects (documentation, budget, ...) and not in creativity and design, the current trends (at least in Spain) are emphasizing the capability of PBL to improve the disciplinary contents learning instead of providing authentic engineering experiences. Of course, any implementation of PBL is better for the learning of skills than a classical expositive course approach but, if a project subject is substituting a given disciplinary subject, the need of providing disciplinary contents drives to the use of contentsoriented methods (puzzles, lectures) which are a bit artificial in a real engineering context. On the other hand, these methods provide ways to assess the individual task of the students which are valuable. In our case, the project subjects are not substituting the disciplinary subjects but supporting them. Looking for a trade-off, we have limited to the first three sessions the disciplinary contents upgrading activities and left the remaining 10 sessions for design-build activities. The generic course schedule is shown in the following table. In the Course Implementation section, more

Table 3
Generic course schedule

Week	Activity	Deliverables
1	- Course introduction - Brainstroming about the product structure and specs. - Puzzle assignment	
2-3	- Puzzle activities about disciplinary contents referred to the project - Block requirements definition	1-2 pages report + 2 slides on each puzzle topic
4	- 3d puzzle about block implementation alternatives - Brainstorming about tasks and work packages planning	Requirement Specification document
5 -8	- Block design and prototyping	Project Plan document Prototype characterization
9-12	- Block improvement and finishing	Second prototype design
13	- Final project presentation	Project final report

details can be found over the example implemented this year.

The documentation has been adapted from the LIPS standard [3]. We started using the LIPS documents in the Introduction to Engineering subject project as they are. After two semesters, we find them a bit complex for small projects and we have simplified the structure of the documents, which are limited to: Requirement Specification, Project Plan, Progress Reports and Final Report.

Course assessment

The initial individual assignments have a small weight in the mark but it is mandatory to deliver them on time. There is a strong penalty (20% per delayed delivery) if less than 80% are delivered on time. Another 20% of the mark is obtained from individual tests about the project contents. The remaining 60% of the mark is assigned to the whole team performance, but there is a 10% which comes from the coherence in the individual marks of the team members, to promote the individual effort. The assessment of the deliverables is based on rubrics which try to take into account both the results and the procedures employed by the students.

- Puzzle and project individual assignments......................20%

(20% penalty in the whole mark if less than 80% on time)

- Project ……………………………………………………………60%
    - 20% half course performance
    - 30% final performance
    - 10% group coherence
- Project contents individual tests (2)……………………….20%

Course implementation

This year, the chosen topic is the design of a component of an in-home audio system, an active loudspeaker able to be powered from the mains AC supply and which would play

Figure 4: Product definition: In-home audio system with wireless digital data streaming

sound coming from a digital source transmitted wirelessly (figure 4).

The system blocks are: a) signal codification-decodification and streaming, b) transmission

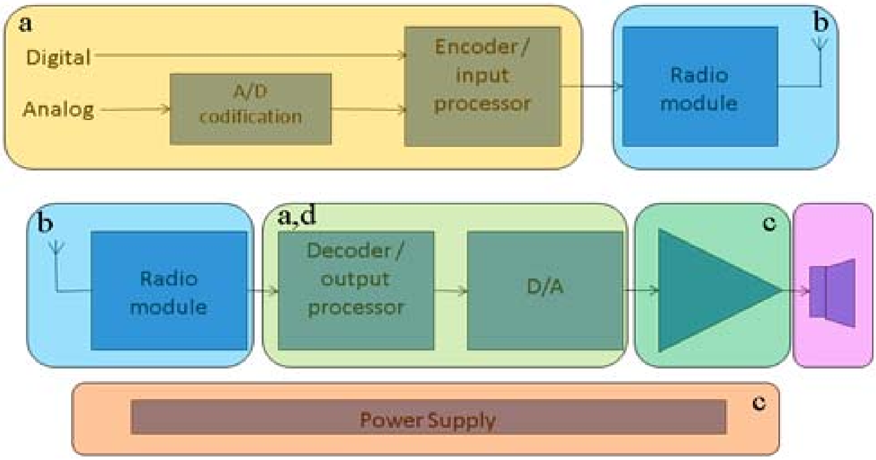

Figure 5: Product block structure and grouping of blocks in sub-projects

(wifi/zigbee/plc), c) amplification and d) digital equalization.

This first year of implementation we are running with a small pilot group of 24 students from electronic engineering and audiovisual systems engineering. Because of this, the system structure and blocks a) and b) are provided by the faculties. The students should design and build the amplifier, characterize it and also the amplifier-loudspeaker set behaviour and preequalize the whole response using Matlab. They have a restriction in cost and in power efficiency (>80%) so they are compelled to choose a D-class switched amplifier structure. Although this amplifier admits a complex implementation and analysis, it can also be understood by sophomore students [4]. The students have completed or are studying two courses on electronic circuits, signal processing and networks. They can only use the basic circuit blocks they know: operational amplifiers, comparators, transistors and filters. The design and implementation includes the following tasks:

- choosing the topology
- designing its main parameters
- simulating its behavioral model
- implementing the circuit blocks
- characterizing them separately and put together
- designing and building the printed circuit board
- characterizing the amplifier-loudspeaker set
- designing the digital equalizer
- characterizing the whole set

- side aspects: selecting a power supply, taking care of electromagnetic interferences.

The first day, after the course introduction, a brainstorming about the product structure and specifications was conducted. Then, the product block breakdown and interface properties were presented by the faculties and the assignment for this year (amplifier + preequalization) was established. The first sessions puzzles have been about audio amplifier structures: the topics have been split in four packages and prepared each one by one of the group members. The first puzzle (second day) was about audio amplifier classes: A, B, A-B, D. The second day, after the experts meeting and the presentation to the group partners, a brainstorming was conducted to extract the conclusions and to drive to the need of choosing a class-D structure after specifying a power efficiency higher than 80%. The second puzzle topics were: Class-D topologies, signal spectrum, output stages and output filters. After the second puzzle activities, the third day, a third bainstorming about pros and cons of the design alternatives was conducted. A third puzzle-like activity was proposed to give individual assignments for the preparation of the Matlab scripts that would be used to perform the behavioural simulation of the amplifier structure. At this point, the assignment for each group was clear and they could prepare the Requirement Specification document with their own interpretation of the given specification. This document includes a background section which is filled by joining and integrating the documents prepared to fulfil the puzzle assignments. Once validated the Requirement Specification, the groups are asked to present the project Plan Document, which includes a Time Plan and a Work Package description. The remaining project weeks, the groups are supposed to follow this plan and are checked at two points: the Preliminary Design Review (PDR), at week 7, when the first prototype should be working and the Critical Design Review (CDR), at week 11, when there is no return in the chosen alternatives and the second prototype should be working, including the pre-equalisation, and only finishing and improving activities should be running. Figure 6 shows the V diagram of the project and table 3 the tollgates. The V diagram shows two parallel groups of tasks because, additionally to the amplifier circuit, they should design two Matlab based virtual instruments (frequency response analyser and audio spectrum analyser + THD measurer)

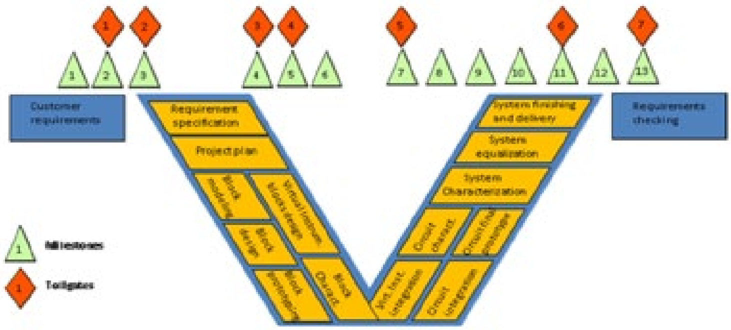

Figure 6: V diagram of the project. While the tollgates are determined by the faculties, the weekly milestones are internal decisions of the groups, according to their project plan.

Table 3
Project tollgates and the corresponding deliverables

#	week	Deliverables
1	2	Puzzle 1
2	3	Puzzle 2
3	4	Blocks models, requirement specification, timeplan proposal
4	5	Project plan
5	7	First prototype evaluation. Progress meeting 1. PDR
6	11	Preequalizer . Progress meeting 2. CDR
7	14	Final results presentation

The next academic year enough students will be enrolled in that course to perform the simultaneous design of all the different blocks of a complex system in different laboratory groups. In the second year project, the students work in depth in the design of a block of a complex system and acquire skills to face the design of a complete complex system in the third year project. The pilot group will reach this project in the next academic year.

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VI. BIOGRAPHICAL INFORMATION

Ramon Bragós is associate professor at the Electronics Engineering Department of Technical University of Catalonia (UPC). His current research focuses on electrical impedance spectroscopy applications in biomedical engineering. He lectures at Telecom BCN, where he is the Associate Dean of Academic Innovation.

Eduard Alarcón is associate professor at the Electronics Engineering Department of UPC. His current research includes signal and energy processing on silicon. He lectures at Telecom BCN, where he is the USA-Liaison Adjunct to the Dean.

Adriano Camps is full professor at the Signal Theory and Communications department of UPC. His current research focuses in microwave remote sensing, with special emphasis in microwave radiometry by aperture synthesis techniques and remote sensing using signals of opportunity. He lectures at Telecom BCN.

Josep Pegueroles is associate professor at the Telematics department of UPC. His current research focuses security for multimedia networked services and secure group communications. He teaches at Telecom BCN.

Albert Oliveras is associate professor at the Signal Theory and Communications department of UPC. His current research focuses in nonlinear image and signal processing and mathematical morphology, and its applications to biological signal processing. He lectures at Telecom BCN.

Miguel García-Hernández is full professor at the Electronics Engineering Department of UPC. His current research focuses in non destructive techniques based on ultrasound and infrared spectroscopy. He lectures at Telecom BCN.

Elisa Sayrol is associate professor at the Signal Theory and Communications department of UPC. Her current research focuses on image and video analysis as well as image and video watermarking. She lectures at Telecom BCN where she is the Dean.

VII. CORRESPONDING AUTHOR

Ramon Bragos
UPC – Technical University of Catalonia
Campus Nord, B3. c/ Jordi Girona 1-3
08034 Barcelona, Spain
sotsdirlabs@etsetb.upc.edu

LEARNING TO CONCEIVE, DESIGN, IMPLEMENT AND OPERATE CIRCUITS AND SYSTEMS

Eduard Alarcón, Ramón Bragós and Elisa Sayrol

Telecommunications School, Campus Nord B3
UPC BarcelonaTech, 08034 Barcelona, Spain
ealarcon@eel.upc.edu

***Abstract*- The type of transversal competences and skills to be acquired by EE students is in open debate. It is argued in this paper that beyond core technical skills and soft skills, the competences of Conceiving, Designing, Implementing and Operating Circuits and Systems are key for a comprehensive electrical engineering education. CAScentric learning activities and methodologies oriented to expose the student to such skills are discussed. This description is carried out both at curriculum architecture level as well as at course level, in the framework of the CDIO approach, an engineering education methodology which considers design-oriented analysis techniques included in an integral project-based learning methodology.**

I. INTRODUCTION

In the current debate about which transversal competences and skills should be acquired by Electrical Engineering students and which methodologies should be considered to induce their learning, it is a common *statu quo* to consider the inputs from various stakeholders -in particular from employing companies and from the Society at large-, which state that EE students are already generally well prepared in core technical skills but that they should enhance their personal (communication) and interpersonal (teamwork) skills. Certainly there is room for improvement in this dimension, since the fact that EE studies are particularly challenging has resulted in the past in the fact that a relevant part of students were deficient in social skills. However, the addition of such personal and interpersonal skills, although of interest, is understood to be common to all professions.

The question arises of whether EE Schools, which in the past have concentrated in analytical skills, can now, beyond adding soft skills, do better as regards technical contents and skills which are specific to Engineering, such as Design.

There is a new trend (to which the CDIO initiative -which stands for Conceive, Design, Implement, and Operate- is aligned [1,2]), which identifies that, beyond core technical skills (as conventionally included in Engineering Colleges) and transversal soft skills (as more recently demanded by Society and companies), the transversal engineering competences of Conceiving, Design, Implementing and Operating Circuits and Systems are key for a comprehensive electrical engineering education, since they constitute the backbone of engineering. This paper deals with these alternative engineeringcentric skills and discusses learning methodologies and activities, best practices and experiences oriented to recover these four skills in Engineering Schools. These aspects, which complement the issue of which technical contents should be included/modified/eliminated in engineering curricula –which is indeed of strong interest, but not addressed here-, affect both courses and curriculum architecture (both by revisiting already existing course contents and adding specific project-based ones). Learning methodologies go beyond learning tools (such as e-learning, or distance-learning), and encompass (design) methodologies, as discussed in this paper.

The structure of the paper is as follows: section II presents the CDIO initiative and discusses learning methodologies and activities, best practices and experiences oriented to expose the students to learn the skills of Conceive, Design, Implement and Operate. It is discussed that the Design skill plays a pivotal role, and techniques to incorporate design skills in curricula and courses are discussed. Section III discusses additional aspects, such as how to address *diversity* in skills and the strength of multiple-impact learning activities. Finally, section IV shows the author’s experience in modifying an EE curriculum considering the perspective presented in this paper, namely including design-oriented analysis methods embedded in integral project-based learning methodology. Emphasis is put in multiple-impact CDIO courses to foster acquisition of engineering competences, orbiting around the central role of Design, while also consolidating more conventional or updated technical contents.

II. CONCEIVE, DESIGN, IMPLEMENT AND OPERATE CIRCUITS/SYSTEMS

2.1 The CDIO Initiative

An initiative exists which originally comes from Aerospace and Mechanical Engineering disciplines, namely the CDIO approach [1, 2, 3], which is cooperatively formed by an open consortium that includes MIT, CU Boulder, KTH, Chalmers and Univ. Auckland, among a growing set of Universities. This engineering education methodology considers a profound and comprehensive change in learning contents and methodologies which is common to all engineering disciplines. One of the core emphasis is in *design* skills, together with a projectbased perspective for tackling complex systems.

Certainly one of the emphasis of the CDIO initiative is to provide skills to develop *products*, this is, of complex systems that target the market and/or Society (in the sense of what is presented in [4] in an effort to include scientific methods to design a product). In that interpretation, C, D, I, O correspond to the four main phases in project development oriented to products, following the well-known "V"-shape project description [1,4].

Compatible with the CDIO rationale, in this work we explore the complementary interpretation of CDIO as the four transversal competences for an engineer, which in particular can be applied to circuits and (complex) systems.

2.2 Learning to Design

It can be stated that the core task of an engineer, and in particular of an EE engineer, is to design. As early identified by the pioneer Caltech professor David R. Middlebrook [5, 6], Engineering Schools migrated decades ago from an scenario in which design was all based in practice and intuition, into an scenario in which, by incorporating the scientific method thorough analytical rigor, students learn to analyze circuits but somehow fail to design them. To avoid that algebra and analysis mask the design process, it was proposed [5, 6, 7] to use low-entropy expressions aimed to design-oriented analysis, to improve the intelligibility of the analytical models describing circuits and systems.

Although indeed the cognitive processes related to the design creativity are partially subconscious, design is not to be mystified. It is not an art or magic, but rather it requires shifting the mindset from analysis to synthesis; for the latter the aim is not to describe analytically per se a circuit or a system but to understand the circuit to be able to dimension its parameters (the lower design layer, parametric design) and/or modify its structure (functional design) [8, 9]. A student can naturally have a certain talent to learn design skills, but they can certainly be fostered through exposure to design problems (particularly to open-ended design problems). Experiences and thoughts aligned to these arguments can be found in recent works [10-15] within the CAS discipline.

A distillation of the design process evolves into the concept of structured design, which has been tackled by the CAS research community [16]. Structured design is a two-fold process, namely: (1) first to appropriately model the interdependencies among a set of performance metrics and the variables that form the multidimensional input design space. (2) Afterwards, appropriate application of optimization tools [17] which lead to a final optimum design in terms of performance metrics. The second part of the design process can be thus carried out automatically, so that the optimum design process relies on the modeling process. This modeling process can be carried out in two ways: (1) by hand calculation, in which the human designer should derive an intuitive low-order analytical model via low-entropy expressions [5], or (2) by computer-based simulations, which come into play to characterize the model when more sophisticated dependencies are required.

Structured design is a must in high-order hierarchy and complex systems [18, 19], as in aerospace applications and multidisciplinary EE projects. Last trends in structured design consider a circuit/system co-design perspective with a translayer approach [20], in which a conceptual and modeling bridge is built among circuit-level characteristics and system-level performance metrics. These approaches can naturally be incorporated in capstone projects.

2.3.Learning to Conceive

Curricula renovation usually includes creativity and entrepreneurship to promote creation of added-value products or even businesses. How to stimulate creativity in a formalized manner –or even with the scientific method- at a circuit or system technical level? Usually, even when facing a design exercise, either the system architecture or the circuit topology is given a priori. Exploring the design space thoroughly can indeed be a way to understand how to circumvent a given circuit or system fundamental limitation, thereby paving the way to conceive an innovative circuit-level or system-level solution that can outperform the precedent circuit or system. The bottom-line of this approach is hence not to teach/learn the "know-how", but to add the "know why", which naturally leads to the question "what if ?" [8] the answer of which is the seed of conceiving novel designs.

Methodological techniques to cultivate in students creativity skills exist which can be incorporated in active learning courses. At a project or product level, usually brainstorming is considered as a technique to generate new ideas through –versed- debate, which can be judged afterwards through critical thinking to select candidate solutions. Master ideas on how to instill creativity (and be cautious to protect inventions) in EE are discussed in [21]. In particular, analogy is a very powerful tool [22] to conceive novel circuits and systems. Once it is understood the "how?" and the "why?" of a given circuit/system principle, in order to answer the "what if?" question, analogies to solutions in other subtopics are a way to provide a solution, and the students should soon learn such cognitive technique. Analogy can be even used to apply to engineering, and in particular to circuit/system design, techniques which can be successfully applied to solve mathematical problems (see from the classical texts [23, 24] to the more recent [25]).

2.4 Other aspects of a CDIO-oriented Curriculum change

Incorporating any additional content to a curricula or a course, by virtue of the communicating vessels principle, is seemingly detrimental to other contents, which should be reduced in extension or depth. A solution to such situation considers multiple-impact learning activities. Such activities are devised so that concurrently design skills together with soft skills are covered and mutually reinforced while revisiting core technical skills.

Also, in front of a conventional EE curriculum which provides common knowledge and competences for an average student profile, diversity in profiles should be considered attending to the various student interests and talents. This approach (later discussed around figure 2) can be extended to the CDIO skills. A learning context for

CDIO skill diversity exposes students to all four skills but can emphasize a given skill to a particular student. Specialization is then at technical and at skill levels; as examples a given student could master CDIO in antennas, CDIO in RF transceiver circuits or CDIO in microprocessor circuits.

III. A CASE EXAMPLE: CDIO IN ELECTRICAL ENGINEERING AT UPC

Telecom BCN, the School of Telecommunication Engineering of Barcelona at UPC Barcelona Tech, is considering the CDIO approach method, in the reform of the Telecom and Electrical Engineering degrees in the convergence towards the Bologna model in Europe. CDIO has been chosen as a paradigm for new curricula design and its syllabus has been fundamental to identify the learning outcomes of our study plans. This complete approach to exercise (and thus to learn) the design of Circuits and Systems, clearly delimits the need for computers and simulations, the need for design-oriented analysis towards optimum designs, and the use of both for conceiving innovative Circuits and Systems solutions. The change process was started three years ago to design new curricula within the frame of the European Higher Education Area (Bologna process), after a study of the state-of-the art in EE curricula [26]. The adaptation to the Bologna process has fostered to perform an in-depth reorganization and to identify the appropriate learning outcomes. Under a new strategic plan, we set up the main goals to design the new curricula. Learning outcomes from well-known models used in several universities in Europe and the United States (ABET, Tuning, CDIO,...) were analyzed.

In this section, first we´ll show comparisons among representative skill models. Afterwards, we will explain how ten generic skills have been chosen as a common characteristic of all our five 4-year bachelor degrees. These generic skills at different levels of difficulty define skill pathways though the curricula involving all courses. Every subject may contribute to the learning of several skills at a given level and actively contribute to develop and assess two of them. On the other hand, four specific CDIO project courses have been scattered along the curricula at the second semester of each academic year to reinforce concepts and skills.

Comparison of skills provided by different frameworks

In order to choose a significant and reduced number of skills towards covering all aspects of the education of engineers we performed different comparison between different frameworks. Some of the skills are mandatory in our University; some others are very well-known across other universities in Europe and the US. Our comparison tables have their main focus in the second level of the CDIO syllabus [1].

The following conclusions can be drawn. The skills originally required by our University were restricted to the so-called soft skills, leaving the aspects related to the practice of engineering to the field of specific skills (content), different for every engineering discipline and therefore not included as compulsory changes. However, other standards and recommendations emphasize common skills across all engineering studies. In any case, we observed that if the CDIO skills were chosen, the compulsory soft skills would be covered by far. CDIO goes well beyond by considering skills like System Thinking and Conceiving and Designing Engineering Circuits and Systems.

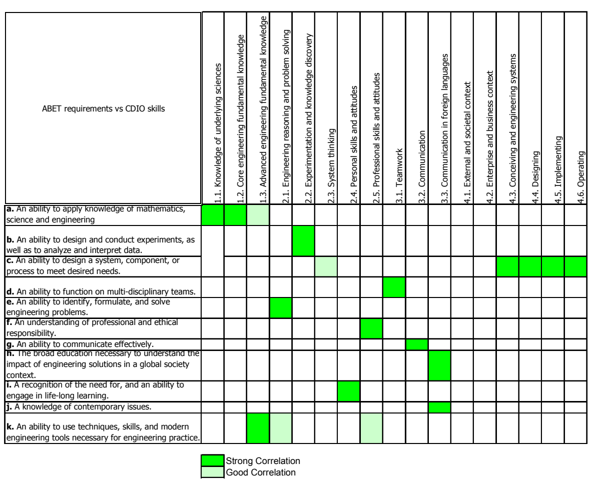

Fig 1. Comparison of ABET requirements and CDIO second-level skills

A comparison of ABET requirements and CDIO second level skills is shown in figure 1. Although these two frameworks are quite close, there are some advantages in using CDIO. CDIO is more clearly organized and contains a higher level of details when implementation is required, providing measurable goals that are critical to curriculum design and assessment. We also observed that Business skills are not so explicitly covered by ABET. As a conclusion, CDIO skills, shown here in their second level for comparison, are convenient since they cover all aspects of engineering required by our University system, as well as covering other well-known frameworks like ABET. Furthermore CDIO skills are clear and concise, and above all, they are focus on the design-related skills as discussed in section II.

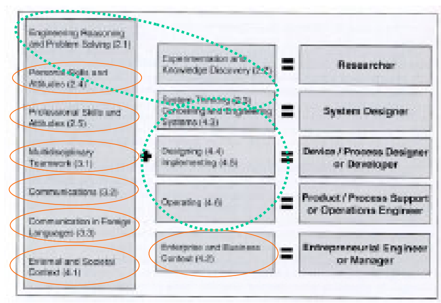

Fig 2. Combinations of transversal skills that give rise to identifying diverse profiles partially covered by soft skills (orange) and areas to be covered (green) by design-centric CDIO skills (adapted from [1]]

Once CDIO was identified, the second step was to define a reduced number of generic skills as expected by our University. The process we followed is summarized in Figure 2. CDIO generic competencies are grouped in two columns. A common block to all degree tracks (left) that combined with specific skills on the central column, give rise to different engineering profiles. Orange ellipses indicate skills covered, although partially, by conventional soft skills requirements. Green ellipses identify two groups [Engineering Reasoning and Problem Solving, experimentation, system thinking] and [Conceiving, Designing, Implementing, Operating] that should be incorporated in order to cover all desirable professional profiles.

Thus, in addition to generic soft skills usually required by University management teams, companies and Society (namely: 1. Innovation and entrepreneurship 2. Societal and environmental context 3. Communication in a foreign language 4. Oral and written communication 5. Teamwork 6. Survey of information resources 7. Autonomous learning), three additional skills were chosen to be compliant with all frameworks and which are described in the following:

8. *Ability to identify, formulate and solve engineering problems*. Ability to pose and solve engineering problems in the ICT field with initiative, decision making and creativity. Ability to develop a systematic and creative method of analysis and problem solving.

9. *Ability to conceive, design, implement and operate complex systems in the field of ICT*. Ability to cover the entire life cycle (conception, design, implementation and operation) of a product, process, system or service in the ICT field. This includes project development in the area of expertise, knowledge of the basic materials and technologies, decision making, management of project activities, conducting measurements, calculations and assessments, management of specifications, regulations and mandatory standards, assessment of social and environmental impact of technical solutions, economic and material evaluation, human resources involved in the project, all of them with a systemic and integrated perspective.

10. *Experimentation and knowledge of instrumentation*. Ability to function comfortably in a lab environment in the ICT field. Ability to operate instrumentation and tools in the telecommunication and electronic engineering field. Understand and operate with manuals and specifications. Ability to assess the errors and limitations associated with measurements and simulation results.

All skills are defined in three levels of difficulty. An example is given for skill 8:

8.1 (basic level). Identify the complexity of the issues addressed in the different courses. Properly provide the solution from a proposed problem statement. Identify different options for resolution. Choose an option, implement and identify it, change if a solution is not reached. Come up with available tools or methods to verify if a solution is correct or at least consistent. Identify the role of creativity in science and technology.

8.2 (medium level). Identify, model and create problems from open situations. Explore alternatives for resolution, choose the best alternative according to a criterion. Manage approximations. Propose and implement methods to validate the usefulness of the solutions. Have a vision of a complex system and the interactions between its components.

8.3 (advanced level). Identify and model complex systems. Identify appropriate methods and tools to set the appropriate equations or descriptions associated with the models and solve them. Conduct qualitative analysis and approximations. Define the uncertainty of the results. Propose hypotheses and experimental methods to validate them. Establish and manage trade-offs. Identify and prioritize key components. Develop critical thinking.

Once the generic skills are chosen, the curricula structure is established. The following conditions are taken into account: (1) No specific courses devoted exclusively to generic skills are desired (2) It is recommended that each academic year, generic skills are simultaneously covered by different courses (3) It is not advisable to overload courses (4) It is advisable to assign at least one generic skill to each course (5) Vertical coordination is required to deal with skill achievement by the students.

Thus, skill pathways were defined by involving all courses. Every course may contribute to the learning of several of the ten skills at a given level (basic, medium, advanced) and should actively contribute to develop and assess two of them. This approach is in accordance with various frameworks, and in particular the CDIO initiative proposes to build an integrated curriculum [1] with the skills embedded in the courses.

CDIO also proposes to insert different courses along the curriculum exclusively devoted to projects (built-in experiences) in which, there are naturally various skills, both personal and interpersonal, as well as specific design engineering skills that are exercised in practice. In particular, it is recommended to carry out a specific course in the first year of studies where an introduction to engineering and a first project help students to identify the context in which they will develop their education and properly focus the other companion courses. This is, to consider generic skills as a learning context of engineering and not its content, which will consist of the specific competences related to the different courses.

Thus, the curriculum includes in its structure a number of courses devoted to develop projects that should not be seen as containers of skills but they must have a triple impact: (1) Consolidate the learning of course contents to be pursued above and in parallel. (2) Motivate the student (3) Work in the engineering context and, therefore, provide a framework to naturally develop most of the generic and specific skills.

Courses devoted to projects ensure proper achievement of the objectives and provide an adequate conceptual basis at every academic level. They are reinforced with seminars on very specific aspects of project management, information management and teamwork. These seminars are spread throughout the curriculum within the course project with the aim of putting the concepts into practice right away.

A categorization of three types of courses is finally as follows:

1. Project courses:
Introduction to ICT Engineering, during the first year. It introduces the engineering discipline. It sets fundamental concepts for identifying tasks, skills and framework in engineering. It motivates learning skills. A seminar series devoted to complex ICT systems (including cochlear implants, silicon chips, underwater communications, communication satellites, internet) in which it is emphasized what is common in seemingly very different complex systems.

Basic ICT Engineering Project (second year), *Advanced ICT Engineering Project* (third year), *Final Degree Project* (fourth year). They introduce complexity in a gradual way. They can fit all the skills that should be allocated and prioritized. Specific seminars are given (patents, conflict management, sustainability, etc.). It sdmits projects targeting diverse professional orientations: research, technical design of product, process or service, product and economic aspects.

2. *Courses with active methodologies*, which carry out active learning activities, laboratory (experimentation), cooperative learning, problem-based learning or case study.

3. Courses with a more conventional approach, within which the insertion of any of the CDIO skills is encouraged. Identify and reinforce best practices already considered in the current curricula, related to the formulation and problem solving and enhance the relationship of skills with a selection of appropriate examples and case studies, providing information on the problem context and guiding the analysis as part of the design process (Design-Oriented Analysis).

IV. CONCLUSIONS

In the current context of debating which transversal competences and skills should be acquired by EE students and the related methodologies to induce their learning, it is discussed in this paper that beyond core technical skills (as conventionally included in Engineering Colleges) and soft skills (as more recently demanded by Society and companies), the competences of Conceiving, Design, Implementing and Operating Circuits and Systems are key for a comprehensive electrical engineering education. Methodologies to foster the active learning of such four engineering competences are revisited and discussed. For a particular curriculum in the conception and design of which the authors have been involved, the description of learning activities and methodologies oriented to expose the student to such skills is described both at a curriculum architecture level as well as at course level, in the framework of the CDIO approach, an engineering education methodology which considers design-oriented analysis methods included in an integral project-based learning methodology. Emphasis is put in multiple-impact CDIO courses to foster acquisition of engineering competences, orbiting about the pivotal role of Design, while also consolidating more conventional technical contents.

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MIXED INTEGRATION OF CDIO SKILLS INTO TELECOMMUNICATION ENGINEERING CURRICULA

Author(s)

E. Sayrol, R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas, J. O'Callaghan, J. Pegueroles, E. Pla, L. Prat, G. Sáez, J. Sardà, C. Tallón

Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona
Universitat Politècnica de Catalunya. Barcelona Tech
Campus Nord UPC, ed B3
c/Jordi Girona 1-3,
08034 Barcelona, Spain
Tel: +344016832.
Email: elisa.sayrol@upc.edu, rbb@eel.upc.edu,ealarcon@eel.upc.edu

I. INTRODUCTION

Engineering of Barcelona at Universitat Politècnica de Catalunya (UPC), Barcelona Tech, we started three years ago the design of new curricula into the frame of the European Higher Education Area (Bologna process). The adaptation to the Bologna process has allowed us to perform an in-depth reorganization and to identify the appropriate learning outcomes.

Under a new strategic plan, we set up the main goals to design the new curricula. Learning outcomes from wellknown models used in several universities in Europe and the United States (ABET, Tuning, CDIO,...) were analyzed. We compared them with the requirements established by our Institute of Science Education and the requirements for verification of academic qualifications set by the Spanish laws. Reports of industry representatives and public institutions were also taken into account [1].

In this paper, we first show comparisons among representative models of skills, including the ones that are mandatory in Spain and in our University. CDIO has been chosen as a paradigm for new curricula design and their syllabus have been fundamental to identify the learning outcomes of our study plans.

Afterwards, we will explain how ten generic skills have been chosen as a common characteristic of all our 4- year bachelor degrees. These generic skills at different levels of difficulty define skill pathways though the curricula involving all subjects. Every subject may contribute to the learning of several skills at a given level and actively contribute to develop and assess two of them. On the other hand, four specific project courses have been scattered along the curricula, at the second semester of each academic year to reinforce concepts and prepare students to work in a company or business environment.

II. COMPARISON OF SKILLS GIVEN BY DIFFERENT FRAMEWORKS

In order to choose a significant and reduced number of skills towards covering all aspects of the education of engineers we perform different comparison between different frameworks. Some of the skills are mandatory in our University and in our country, some others are very well-known across prestigious universities in Europe and the US.

Our comparison tables have its main focus in the second level of the CDIO syllabus [2] and are shown in Figures 1, 2 and 3. The following conclusions can be drawn.

Comparison of CDIO second level skills with UPC required skills. As shown in Figure 1, UPC skills [3] are restricted to the so-called soft skills, leaving the aspects related to the practice of engineering to the field of specific skills (content), different for every engineering discipline and therefore not included. However, other standards and recommendations emphasize common skills across all engineering studies. In any case, we observe that if the CDIO skills were chosen, UPC soft skills would be covered.

Comparison of Spanish laws for telecommunication engineering curricula and CDIO second level skills. Spanish bachelor degrees in engineering that lead to professional activities are regulated by law. In particular for telecommunications (electrical) engineering degrees [4] the laws specify some generic skills as well as some specific skills. Generic skills in this case include soft skills and some generic engineering skills. Specific skills are related to the traditional contents of curricula. Our goal in this case is to compare generic skills of the Spanish law requirements and the second level of CDIO skills. We see that CDIO again can cover these requirements with a more simple approach. CDIO goes beyond by considering skills like *System Thinking and Conceiving and Engineering Systems* that are not explicitly considered in the Spanish law. We also observed in another comparison, not included here, that UPC skills were insufficient to cover Spanish law generic skills.

Comparison of ABET requirements and CDIO second level skills. This comparison is reproduced here from [2]. Although these two frameworks are quite close there are some advantages in using CDIO. CDIO is more clearly organized and contains more level of details when implementation is required, providing measurable goals that are critical to curriculum design and assessment. ABET was also compared to Spanish law generic skills in our study. We also observed that *Enterprise and Business Context* skills are not so explicitly covered by ABET.

As a conclusion, CDIO skills, shown here in their second level for comparison, are quite convenient since they cover all aspects of engineering required by our University system and the Spanish law, as well as covering other well-know frameworks like ABET. Furthermore CDIO skills are clear and concise.

III. DEFINITION OF GENERIC SKILLS AT TELECOM BCN

Once CDIO was identified, the second step was to define a reduced number of generic skills as expected by our University.

The process we followed is summarized in Figure 4. CDIO generic competencies are grouped in two columns. A common block to all career tracks (left) that combined with specific skills on the central column, give rise to different engineering profiles. Orange continuous line ellipses indicate skills covered, although partially, by UPC requirements. Green dashed ellipses identify two groups [Engineering Reasoning and Problem Solving, experimentation, system thinking] and [Conceiving, Designing, Implementing, Operating] that should be addressed in order to cover all professional profiles.

Thus, in addition to generic skills proposed by UPC:

1. Innovation and entrepreneurship
2. Societal and environmental context
3. Communication in a foreign language (English)
4. Oral and written communication
5. Teamwork
6. Survey of information resources
7. Autonomous learning

three additional skills were chosen to be compliant with all frameworks:

8. Ability to identify, formulate and solve engineering problems
9. Ability to conceive, design, implement and operate complex systems in the field of Information and Communication Technologies
10. Experimentation and knowledge of instrumentation

These three additional generic skills can be further described as follow:

8. *Ability to identify, formulate and solve engineering problems.*

Ability to pose and solve engineering problems in the ICT field with initiative, decision making and creativity. Ability to develop a method of analysis and problem solving systematic and creative.

9. *Ability to conceive, design, implement and operate complex systems in the field of ICT.*

Ability to cover the entire life cycle (conception, design, implementation and operation) of a product, process, system or service in the ICT field. This includes writing and project development in the area of expertise, knowledge of the basic materials and technologies, decision making, management of activities under the project, conducting measurements, calculations and assessments, management of specifications, regulations and mandatory standards, assessment of social and environmental impact of technical solutions, economic and material evaluation, human resources involved in the project, with a systemic and integrated perspective.

10. *Experimentation and knowledge of instrumentation*

Ability to function comfortably in a lab environment in the ICT field. Ability to operate instrumentation and tools in the telecommunication and electronic engineering field. Understand and operate with manuals and specifications. Ability to assess the errors and limitations associated with measurements and simulation results.

The last skill could be considered included in the 8 and 9 but it was the desire of our faculty to keep explicitly one of the most positive aspects of our previous curriculum, conceived in 1992, which was the commitment to experimentation

All skills are defined in three levels of difficulty. Here we show an example for skill 8:

8.1 (basic level). Identify the complexity of the issues addressed in the different subjects. Properly raise the solution from a proposed problem statement. Identify different options for resolution. Choose an option, implement and identify, change if a solution is not reached. Come up with available tools or methods to verify if a solution is correct or at least consistent. Identify the role of creativity in science and technology.

8.2 (medium level). Identify, model and create problems from open situations. Explore alternatives for resolution, choose the best alternative according to a criterion. Manage approximations. Propose and implement methods to validate the usefulness of the solutions. Have a vision of a complex system and the interactions between its components.

8.3 (advanced level). Identify and model complex systems. Identify appropriate methods and tools to set the appropriate equations or descriptions associated with the models and solve them. Conduct qualitative analysis and approximations. Define the uncertainty of the results. Propose hypotheses and experimental methods to validate them. Establish and manage commitments. Identify and prioritize key components. Develop critical thinking.

The seven generic UPC skills in its three levels of achievement are described in [3].

IV. INTRODUCING GENERIC SKILLS IN THE TELECOMMUNICATION ENGINEERING CURRICULA

Once the generic skills are chosen the curricula structure is established. The following conditions are taken into account:

- No specific subjects devoted exclusively to generic skills are desired
- It is recommended that each academic year, generic skills are simultaneously treated from different subjects
- It is not advisable to overload subjects
- It is advisable to assign at least one generic skill to each subject
- Vertical coordination is required to deal with skill achievement by the students

Thus, skills pathways were defined by involving all subjects. Every subject may contribute to the learning of several of the ten skills at a given level (basic, medium, advanced) and should actively contribute to develop and assess two of them. This approach is in accordance with various frameworks and in particular the CDIO initiative proposes to build an integrated curriculum, with the skills embedded in the subjects.

CDIO also proposes to insert different subjects along the curriculum exclusively devoted to projects (builtin experiences) in which, naturally, there are various skills, both personal and interpersonal, as well as specific engineering skills that are put into practice. In particular, it is recommended to carry out a specific subject in the first year of studies where an introduction to engineering and a first project help students to identify the context in which they will develop their training and properly focus on other subjects. It is, in short, to consider generic skills as a learning context of engineering and not its content, which will consist of the specific competences of the different subjects.

Thus, the curriculum includes in its structure a number of subjects devoted to develop projects that should not be seen as containers of skills but they must have a triple impact:

- Consolidate the learning of subject content to be pursued in parallel and above.
- Encourage the student.
- Working in the engineering context and, therefore, provide a framework to develop naturally most of the generic and specific skills. Subjects devoted to projects ensure proper achievement of the objectives and provide an adequate conceptual basis at every academic level. They are reinforced with seminars on very specific aspects of project management, information management and teamwork. These seminars are spread throughout the curriculum within the subject project with the aim of putting the concepts into practice right away.

We then define the following groups of subjects:

1. Project subjects:

In the first year:

Introduction to ICT Engineering. The main features are the following. It introduces the engineering discipline.

It sets fundamental basis identifying tasks, skills and framework in engineering. It motivates learning skills. Generic skills are first introduced such as oral and written communication, teamwork, introduction to CDIO. Training sessions in economics and business and a short project is addressed.

During the second, third and fourth year:

Basic Project in Engineering (second year), Advanced Project in Engineering (third year), Final Degree Project (fourth year). The main features are the following. They introduce complexity in a gradual way. They can fit all the skills that should be allocated and prioritized. Specific seminars are given (patents, conflict management, sustainability, etc.). Admits projects targeting diverse professional orientations: research, technical design of product, process or service, product and economic aspects

2. Subjects with active methodologies:

Subjects that carry out active learning activities, laboratory (experimental), Cooperative learning; Problem based learning or case study; Short projects and work with oral presentations and written report

3. Subjects with a more "classical" approach:

They can promote the insertion of any of the skills. Identify issues that they take place nowadays, related to formulation and problem solving and enhance the relationship of skills with a selection of appropriate examples and case studies, giving information on the context of the problem and looking to guide the analysis as part of the design process (Design-Oriented Analysis)

Specific study plans with the described approach can be obtained from our web page [5].

V. CONCLUSIONS

The new curricula adapted to EHEA at Telecom BCN, have a structure that encourages the learning of generic skills through a blended formula. First all subjects include a reduced number of skills that define vertical pathways so every one of the Telecom BCN skills are practiced at least in three different subjects in three different levels. Second, project subjects are defined at every academic year to strengthening the learning of the contents of other subjects and to develop generic skills naturally through activities close to the practice of engineering. This scheme is compatible with the standards defined by the CDIO initiative, which Telecom BCN has joined in July 2009.

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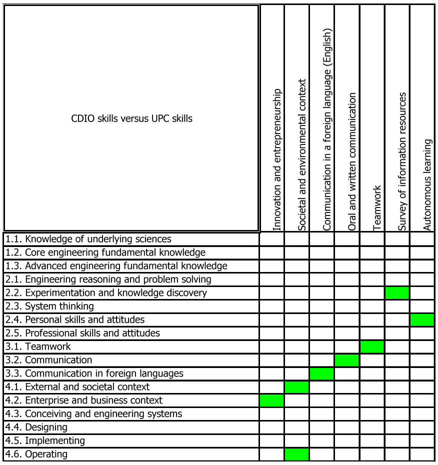

Fig 1. Comparison of CDIO second level skills with UPC required skills. Common skills are indicated.

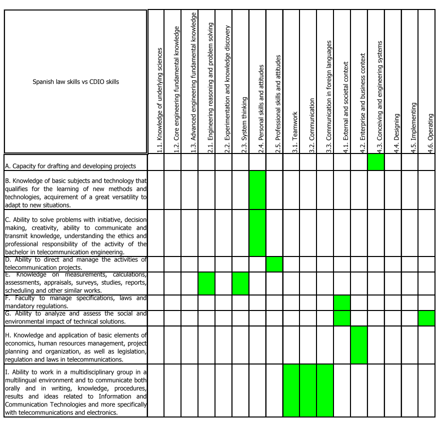

Fig 2. Comparison of Spanish laws for telecommunication engineering curricula and CDIO second level skills.

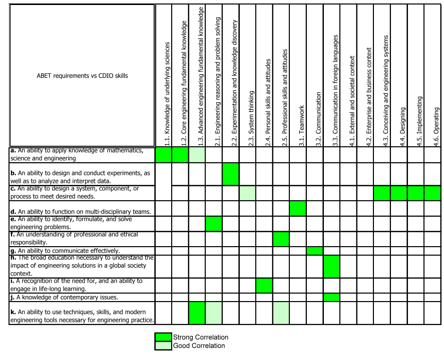

Fig 3. Comparison of ABET requirements and CDIO second level skills [3].

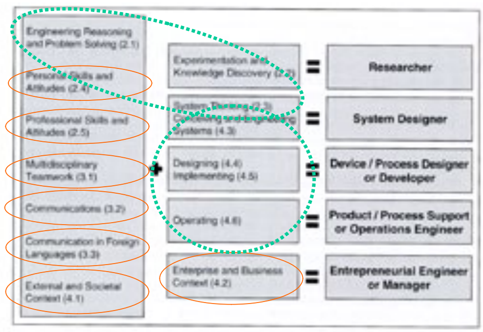

Fig 4. Adapted from [3]. Combinations of generic skills that give rise to identifying distinct profiles partially covered by UPC skills (orange) and areas to be covered (green).

E. Sayrol, R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas, J. O'Callaghan, J. Pegueroles, E. Pla, L. Prat, G. Sáez, J. Sardà, C. Tallón. **Mixed Integration of CDIO skills into Telecommunication Engineering Curricula**// Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. ISBN: 978-955-25-826-1

Abstract. Spain has been intensively involved in designing engineering curricula for the last two years and next academic year all engineering schools will be deploying all bachelor programs adapted to the EHEA and to the Spanish laws. The different frameworks that set the conditions of the process of drawing up new curricula emphasize the use of competency-based learning and the insertion of certain generic skills within the structure of the new plans. In the school of Telecommunication Engineering of Barcelona, the CDIO initiative (Conceive-Design-Implement-Operate) first developed jointly by MIT and some Swedish Universities, has been chosen as paradigm for new engineering curricula design. We used a mixed approximation to integrate CDIO skills into the study plans. In this paper we will explain the approach to include generic skills when designing new curricula.

PROCESO DE INSERCIÓN DE COMPETENCIAS GENÉRICAS EN LOS NUEVOS PLANES DE ESTUDIOS DE GRADO DE LA ETSETB DE ACUERDO CON EL MODELO CDIO

Author(s)

R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas,

J. O'callaghan, J. Pegueroles, I. Prat, G. Sáez, J. Sardà y E. Sayrol

Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona.

Universitat Politècnica de Catalunya. Barcelona

sotsdirinnovacio@etsetb.upc.edu

Los distintos marcos normativos que fijan las condiciones de contorno en la elaboración de los nuevos planes de estudios ponen especial énfasis en el aprendizaje basado en competencias y en la inclusión de determinadas competencias genéricas. Después de comparar diversos planes de estudio y listados de competencias, se han establecido las competencias genéricas que deben incluir los nuevos grados de la ETSETB de la UPC y se ha diseñado su estructura para favorecer su aprendizaje. Para ello se ha utilizado como paradigma el modelo CDIO (Conceive, Design, Implement, Operate).

Palabras clave: Plan de estudios, Competencias genéricas, CDIO

I. INTRODUCCIÓN

Los diferentes marcos que fijan las condiciones de contorno del proceso de confección de los nuevos planes de estudios hacen énfasis en el uso del aprendizaje basado en competencias y en la inserción de determinadas competencias genéricas dentro de la estructura de los nuevos planes. Los informes de la comisión externa de expertos en el ámbito de la Ingeniería de Telecomunicación y del consejo asesor de la Escuela formado por representantes empresariales y de instituciones públicas también recogen indicaciones en el mismo sentido. Para adoptar este nuevo enfoque del proceso educativo, la Escuela Técnica Superior de Ingeniería de Telecomunicación de Barcelona (ETSETB, UPC) arrancó en enero de 2008 el proceso de elaboración de un nuevo Plan Estratégico como marco para la confección de los nuevos Planes de Estudios de Grado. Dentro de esta acción se detectó la necesidad de encontrar una metodología que permitiera incorporar el aprendizaje por competencias.

Se han estudiado tanto los materiales propuestos por el ICE de la UPC [1] como los requisitos para la verificación de los títulos universitarios oficiales que habiliten para el ejercicio de la profesión de Ingeniero Técnico de Telecomunicación [2], así como diversos listados de competencias (ABET, Tuning, ...). Adicionalmente, se analizaron [3] un conjunto de planes de estudios recientemente establecidos en diversas Universidades de prestigio internacional, con objeto tanto de fomentar la incorporación en el debate de las iniciativas llevadas a cabo por dichas Universidades, como de avalar la toma de decisiones en los aspectos más controversiales. Así, a partir de los respectivos planes de estudios, se extrajo y destiló la información necesaria para identificar aspectos tanto de la estructura del plan de estudios, como de metodología educativa y de garantía de calidad, a saber: (a) la existencia de diferentes tipos de grado (comunicaciones, telemática, electrónica, audio/video), (b) duración de los grados y master (c) curso de introducción a la ingeniería (d) curso de culminación *capstone* (e) investigación en pregrado (f) competencias específicas de ingeniería (g) competencias genéricas (h) criterios, métodos e instrumentos de evaluación. La comparativa incluyó, entre otras, MIT, Standford, UC Berkeley, Columbia, Wisconsin-Madison, GeorgiaTech, McGill, Toronto, Auckland, HongKong Polytechnic, KAIST, TU München, RWTH Aachen, DTU, KTH, Telecom Paris, Politecnico di Milano, ETH Zürich.

Respecto a las competencias genéricas y restringiéndonos a los que consideramos más representativos y a los que, por cuestiones normativas debemos atendernos, mostramos a continuación de forma resumida los listados de competencias definidos por la UPC (Tabla 1), el Ministerio (Tabla 2), ABET (Tabla 3) y CDIO (Tabla 4):

Tabla 1. Competencias genéricas definidas por el marco UPC, a incluir por todos los planes de estudios con la recomendación de ampliarlas hasta un máximo de 10.

1.	Emprendeduría e innovación
2.	Sostenibilidad y compromiso social
3.	Tercera lengua (inglés)
4.	Comunicación eficaz oral y escrita
5.	Trabajo en equipo
6.	Uso solvente de los recursos de información
7.	Aprendizaje autónomo

Tabla 2. Competencias Orden Ministerial Anexo I del borrador (octubre 2008).

A.	Capacidad para redactar y desarrollar proyectos en el ámbito de su especialidad.
B.	Conocimiento de materias básicas y tecnologías, que le capacite para el aprendizaje de nuevos métodos y tecnologías, así como que le dote de una gran versatilidad para adaptarse a nuevas situaciones.
C.	Capacidad de resolver problemas con iniciativa, toma de decisiones, creatividad, y de comunicar y transmitir conocimientos, habilidades y destrezas, comprendiendo la responsabilidad ética y profesional de la actividad del ingeniero técnico de telecomunicación.
D.	Capacidad para la dirección de las actividades objeto de los proyectos del ámbito de su especialidad.
E.	Conocimientos para la realización de mediciones, cálculos, valoraciones, tasaciones, peritaciones, estudios, informes, planificación de tareas y otros trabajos análogos en el ámbito de su especialidad.
F.	Facilidad para el manejo de especificaciones, reglamentos y normas de obligado cumplimiento.
G.	Capacidad de analizar y valorar el impacto social y medioambiental de las soluciones técnicas.
H.	Conocer y aplicar elementos básicos de economía y de gestión de recursos humanos, organización y planificación de proyectos, así como de legislación, regulación y normalización en las telecomunicaciones.
I.	Capacidad de comunicar, tanto por escrito como de forma oral, conocimientos, procedimientos, resultados e ideas relacionadas con las telecomunicaciones y la electrónica.
J.	Capacidad de trabajar en un grupo multidisciplinar y en un entorno multilingüe y de comunicar, tanto por escrito como de forma oral, conocimientos, procedimientos, resultados e ideas relacionadas con las telecomunicaciones y la electrónica.

Tabla 3. Resultados del aprendizaje de los programas de ingeniería según ABET

a.	An ability to apply knowledge of mathematics, science and engineering
b.	An ability to design and conduct experiments, as well as to analyze and interpret data.
c.	An ability to design a system, component, or process to meet desired needs.
d.	An ability to function on multi-disciplinary teams.
e.	An ability to identify, formulate, and solve engineering problems.
f.	An understanding of professional and ethical responsibility.
g.	An ability to communicate effectively.
h.	The broad education necessary to understand the impact of engineering solutions in a global society context.
i.	A recognition of the need for, and an ability to engage in life-long learning.
j.	A knowledge of contemporary issues.
k.	An ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

Tabla 4. CDIO Syllabus. Listado de competencias de nivel 2. El detalle de nivel 3 comprende 70 ítems [4].

1 Technical knowledge and reasoning 1.1. Knowledge of underlying sciences 1.2. Core engineering fundamental knowledge 1.3. Advanced engineering fundamental knowledge
2 Personal and professional skills and attributes 2.1. Engineering reasoning and problem solving 2.2. Experimentation and knowledge discovery 2.3. System thinking 2.4. Personal skills and attitudes 2.5. Professional skills and attitudes
3 Interpersonal skills: teamwork and communication 3.1. Teamwork 3.2. Communication 3.3. Communication in foreign languages
4 Conceiving, designing, implementing and operating systems in the enterprise and societal context 4.1. External and societal context 4.2. Enterprise and business context 4.3. Conceiving and engineering systems 4.4. Designing 4.5. Implementing 4.6. Operating

II. COMPARACIÓN DE LOS LISTADOS DE COMPETENCIAS

Se han llevado a cabo tablas de comparación cruzada entre los distintos listados, teniendo en cuenta su descripción detallada en los casos en que ésta existe. Se muestran a continuación dichas tablas. La comparación entre los estándares CDIO y ABET puede encontrarse en [4].

Tabla 5. Correlación entre las competencias del Syllabus CDIO y el Marco UPC

CDIO vs Marco UPC	1	2	3	4	5	6	7
1.1. KNOWLEDGE OF UNDERLYING SCIENCES							
1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE							
1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE							
2.1. ENGINEERING REASONING AND PROBLEM SOLVING							
2.2. EXPERIMENTATION AND KNOWLEDGE DISCOVERY						x	
2.3. SYSTEM THINKING							
2.4. PERSONAL SKILLS AND ATTITUDES							x
2.5. PROFESSIONAL SKILLS AND ATTITUDES							
3.1. TEAMWORK					x		
3.2. COMMUNICATION				x			
3.3. COMMUNICATION IN FOREIGN LANGUAGES			x				
4.1. EXTERNAL AND SOCIETAL CONTEXT		x					
4.2. ENTERPRISE AND BUSINESS CONTEXT	x						
4.3. CONCEIVING AND ENGINEERING SYSTEMS							
4.4. DESIGNING							
4.5. IMPLEMENTING							
4.5. OPERATING		x					

Tabla 6. Correlación entre las competencias del Syllabus CDIO y la ficha definida por la Orden Ministerial Anexo I del borrador (octubre 2008) para la Ingeniería Técnica de Telecomunicación

CDIO vs Ficha ITT	A	B	C	D	E	F	G	H	I
1.1. KNOWLEDGE OF UNDERLYING SCIENCES									
1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE									
1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE									
2.1. ENGINEERING REASONING AND PROBLEM SOLVING					x				
2.2. EXPERIMENTATION AND KNOWLEDGE DISCOVERY					x				
2.3. SYSTEM THINKING									
2.4. PERSONAL SKILLS AND ATTITUDES		x	x						
2.5. PROFESSIONAL SKILLS AND ATTITUDES									
3.1. TEAMWORK				x					x
3.2. COMMUNICATION									x
3.3. COMMUNICATION IN FOREIGN LANGUAGES									x
4.1. EXTERNAL AND SOCIETAL CONTEXT						x	x		
4.2. ENTERPRISE AND BUSINESS CONTEXT								x	
4.3. CONCEIVING AND ENGINEERING SYSTEMS	x								
4.4. DESIGNING									
4.5. IMPLEMENTING									
4.5. OPERATING							x		

Tabla 7. Correlación entre las competencias Marco UPC y la ficha definida por la Orden Ministerial Anexo I del borrador (octubre 2008) para la Ingeniería Técnica de Telecomunicación

Marco UPC vs ficha ITT	A	B	C	D	E	F	G	H	I
1. Emprendeduría e innovación								x	
2. Sostenibilidad y compromiso social							x		
3. Tercera lengua (inglés)									x
4. Comunicación eficaz oral y escrita			x						x
5. Trabajo en equipo									x
6. Uso solvente de los recursos de información						x			
7. Aprendizaje autónomo		x							

Como puede apreciarse, el marco UPC limita su alcance a las denominadas “soft skills”, ya que los aspectos más relacionados con la práctica de la ingeniería se consideran ligados al ámbito de las competencias específicas (contenidos). Sin embargo, los demás estándares y las recomendaciones de los distintos colectivos hacen hincapié en estas habilidades propias de la ingeniería. En el proceso de comparación, hemos detectado como sistema más completo y estructurado el que propone la iniciativa CDIO [4], desarrollada inicialmente por el MIT y las universidades suecas de Chalmers, KTH y Linköping y a la que hoy se acogen más de 40 programas de instituciones educativas del ámbito de la ingeniería en todo el mundo. La iniciativa CDIO define un listado de competencias (Syllabus) a varios niveles. En la tabla 4 hemos podido ver el nivel 2, pero el detalle de nivel 3 comprende 70 ítems cada uno de los cuales está desarrollado a mayor profundidad que un simple enunciado. Define además 12 estándares para la implantación y seguimiento de dicha metodología. De forma muy resumida, establece que el ciclo de vida de un producto (concepción, diseño implementación y operación) es el entorno idóneo para el estudio de la ingeniería y promueve el aprendizaje de las competencias como el contexto adecuado para el desarrollo de las asignaturas, imbricándolo en ellas y sin entrar en conflicto con los contenidos. Promueve además la adopción de metodologías activas de aprendizaje y la inclusión de diversas actividades de diseño e implementación a lo largo de los estudios.

A modo de resumen del proceso seguido para la definición de las competencias genéricas propias de la ETSETB, en la figura 1 (Adaptada de [4]) se pueden ver las competencias genéricas CDIO agrupadas en dos columnas, de forma que definen un bloque común (izquierda), que, combinado con las específicas de la columna central, dan lugar a los distintos perfiles profesionales de la ingeniería (derecha). Se ha marcado con elipses de color naranja las competencias que, aunque parcialmente, se cubren con las que propone el Marco UPC, y se identifican con elipses verdes dos grandes grupos [engineering reasoning and problem solving, experimentation, system thinking] y [conceiving, designing, implementing, operating]. Estas competencias deberían cubrirse para poder abarcar todos los perfiles profesionales. Se han definido pues 3 competencias adicionales a las propuestas por la UPC de acuerdo con estos criterios y, en su desarrollo a 3 niveles, se han tenido en cuenta los descriptores de los distintos marcos que se mencionan en este documento. Las tres competencias adicionales que se proponen son:

8. Capacidad para identificar, formular y resolver problemas de ingeniería

9. Capacidad para concebir, diseñar, implementar y operar sistemas complejos en el ámbito de las Tecnologías de la Información y las Comunicaciones

10. Experimentalidad y conocimiento de la instrumentación

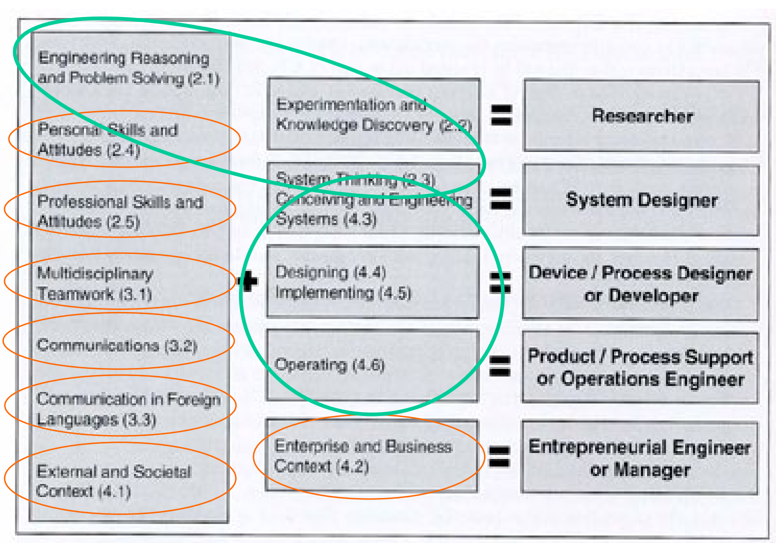

Figura 1. Adaptado de [4], figura 3.6. Combinaciones de competencias genéricas que dan lugar a los distintos perfiles profesionales identificando las que están parcialmente cubiertas por el marco UPC (naranja) y las áreas a cubrir por las nuevas competencias específicas de la ETSETB (verde).

El desarrollo de las 7 competencias UPC puede encontrarse en las guías de trabajo del ICE [5]. Por lo que respecta a las tres nuevas competencias propuestas por la ETSETB, se muestra a continuación su definición básica y el desarrollo de objetivos a nivel elemental, medio y avanzado:

8. Capacidad para identificar, formular y resolver problemas de ingeniería.

Capacidad para plantear y resolver problemas de ingeniería en el ámbito TIC con iniciativa, toma de decisiones y creatividad. Desarrollar un método de análisis y solución de problemas sistemático y creativo.

Objetivos por niveles

8.1 – Identificar la complejidad de los problemas tratados en las materias. Plantear correctamente el problema a partir del enunciado propuesto. Identificar las opciones para su resolución. Escoger una opción, aplicarla e identificar si es necesario modificarla si no se llega a una solución. Disponer de herramientas o métodos para verificar si la solución es correcta o, como mínimo, coherente. Identificar el papel de la creatividad en la ciencia y la tecnología

8.2 – Identificar, modelar y plantear problemas a partir de situaciones abiertas. Explorar las alternativas para su resolución, escoger la alternativa óptima de acuerdo a un criterio justificado. Manejar aproximaciones. Plantear y aplicar métodos para validar la bondad de las soluciones. Tener una visión de sistema complejo y de las interacciones entre sus partes constitutivas.

8.3 – Identificar y modelar sistemas complejos. Identificar los métodos y herramientas adecuados para plantear las ecuaciones o descripciones asociadas a los modelos y resolverlas. Llevar a cabo análisis cualitativos y aproximaciones. Establecer la incertidumbre de los resultados. Plantear hipótesis y proponer métodos experimentales para validarlas. Establecer y manejar compromisos. Identificar componentes principales y establecer prioridades. Desarrollar un pensamiento crítico.

9. Capacidad para concebir, diseñar, implementar y operar sistemas complejos en el ámbito de las TIC.

Capacidad para cubrir el ciclo de vida completo (concepción, diseño, implementación y operación) de un producto, proceso, sistema o servicio en el ámbito TIC. Esto incluye la redacción y desarrollo de proyectos en el ámbito de la especialidad, el conocimiento de las materias básicas y tecnologías, la toma de decisiones, la dirección de las actividades objeto de los proyectos, la realización de mediciones, cálculos y valoraciones, el manejo de especificaciones, reglamentos y normas de obligado cumplimiento, la valoración del impacto social y medioambiental de las soluciones técnicas adoptadas, la valoración económica y de recursos materiales y humanos involucrados en el proyecto, con una visión sistémica e integradora.

Objetivos por niveles

9.1 – Identificar las funciones de la ingeniería y los procesos involucrados en el ciclo de vida de un producto, proceso o servicio. Valorar la necesidad de la sistematización del proceso de diseño. Identificar e interpretar los pasos de un documento de especificación del proceso de diseño (PDS). Completar y mejorar documentos de especificación y planificación. Aplicar un proceso de diseño sistemático en sus fases de implementación y operación. Elaborar informes de progreso de un proceso de diseño. Manejar herramientas de apoyo a la gestión de proyectos. Elaborar un informe final correspondiente a un proceso de diseño sencillo. Conocer los aspectos económicos básicos asociados al producto – proceso- servicio que se está diseñando.

9.2 – Identificar las necesidades del usuario y elaborar una definición de producto-procesoservicio y unas especificaciones iniciales. Elaborar una especificación del proceso de diseño. Diseñar y seguir un modelo de gestión del proceso de diseño basado en un estándar. Conocer profundamente los pasos asociados a las fases de diseño, implementación y operación. Utilizar de forma coherente los conocimientos y herramientas adquiridos en las diferentes materias en el proceso de diseño e implementación. Evaluar y proponer mejoras al diseño realizado. Evaluar la aplicación de la legislación, normativa y regulación de las telecomunicaciones en los ámbitos nacional, europeo e internacional.

9.3 – Identificar las necesidades y oportunidades del mercado. Recoger información que permita elaborar las especificaciones de un nuevo producto proceso o servicio. Elaborar un plan de negocio básico. Concebir un nuevo producto, proceso o servicio. Elaborar y llevar a cabo la planificación de un proceso de diseño. Llevar a cabo las diferentes fases de un proceso de diseño.

10. Experimentalidad y conocimiento de la instrumentación

Capacidad para desenvolverse competentemente en un entorno de laboratorio del ámbito TIC. Capacidad para operar instrumentación y herramientas propias de las ingenierías de telecomunicación y electrónica e interpretar sus manuales y especificaciones. Capacidad de evaluar los errores y las limitaciones asociados a las medidas y resultados de simulaciones.

Objetivos por niveles

G10.1 – Conocer y utilizar correctamente las herramientas, instrumentos y aplicativos software disponibles en los laboratorios de las materias básicas. Seguir los manuales de las prácticas de laboratorio, recoger datos de las medidas y llevar a cabo análisis básicos con ellos.

G10.2 – Utilizar de forma autónoma las herramientas, instrumentos y aplicativos software disponibles en los laboratorios de las materias básicas y avanzadas. Conocer el funcionamiento y las limitaciones de estas herramientas. Entender sus manuales y especificaciones. Analizar los resultados de las medidas y simulaciones críticamente. Llevar a cabo análisis avanzados con los datos.

G10.3 – Diseñar experimentos y medidas para verificar hipótesis o validar el funcionamiento de equipos, procesos, sistemas o servicios en el ámbito TIC. Seleccionar los equipos o herramientas software adecuadas. Valorar críticamente sus especificaciones. Llevar a cabo análisis avanzados con los datos recogidos.

La competencia 10 podría haberse considerado incluida en la 8 y 9 pero se ha querido mantener de forma explícita para consolidar uno de los aspectos más positivos del anterior plan de estudios, que fue la apuesta por la experimentalidad.

III. PROPUESTA DE METODOLOGÍA PARA EL APRENDIZAJE DE LAS COMPETENCIAS GENÉRICAS EN LA ETSETB

Para la inclusión en el plan de estudios de las competencias genéricas citadas en el apartado anterior, se han tenido en cuenta los siguientes criterios:

- No son aconsejables las asignaturas específicas de competencias
- Se recomienda que en cada curso se trabajen de manera simultánea distintas competencias genéricas desde las diferentes asignaturas del curso
- No es aconsejable sobrecargar las asignaturas
- No es aconsejable no asignar ninguna competencia genérica a una asignatura
- Se requerirá coordinación vertical para los itinerarios competenciales

Por otra parte, los diversos marcos, y en particular la iniciativa CDIO, proponen construir un currículum integrado, con las competencias imbricadas en las asignaturas. CDIO propone además insertar diversas asignaturas de proyectos en las que, de manera natural, se desarrollan diversas competencias, tanto personales, interpersonales, como específicas de la ingeniería. En particular, se recomienda llevar a cabo una asignatura específica en primer curso en el que se realice una introducción a la ingeniería y un primer proyecto a fin de que el estudiante pueda identificar el contexto en el que se desarrollará su formación y enfocar correctamente el resto de asignaturas del grado. Se trata, en resumen, de considerar las competencias genéricas como el contexto del aprendizaje de la ingeniería y no su contenido, que seguirá constituido por las competencias específicas de las distintas materias.

Así, los planes de estudio diseñados incluyen en su estructura un conjunto de asignaturas de proyectos que no deben entenderse como contenedores de competencias sino que deben tener un triple impacto:

- Consolidar el aprendizaje de los contenidos de las materias que se cursan en paralelo y de las anteriores.
- Motivar al estudiante
- Trabajar en el contexto de la ingeniería y, como consecuencia, ofrecer un marco para desarrollar de manera natural la mayor parte de las competencias genéricas y específicas.

Se ha incluido una asignatura de 6 créditos ECTS en el segundo semestre de primero, dentro de la materia de economía, en la que además de los conceptos básicos de economía y empresa, se muestra la visión de sistema y de negocio de los distintos productos y servicios del ámbito TIC, la metodología de gestión de proyectos y se lleva a cabo un primer proyecto parcialmente guiado en grupos de 4 estudiantes.

En el segundo semestre de segundo y tercer curso se han programado dos asignaturas de proyectos de ingeniería (proyecto básico y proyecto avanzado) de 6 y 12 créditos ECTS respectivamente. En éstas el 80% del tiempo se dedica a la realización de proyectos abiertos y el 20% a seminarios. El proyecto básico se llevará a cabo en equipos de 5-6 estudiantes y tendrá un contenido fundamentalmente técnico, mientras que el proyecto avanzado lo realizarán grupos grandes de estudiantes (9-12) trabajando en subproyectos que deberán coordinarse entre ellos. Aparte de la componente técnica, tendrán una fuerte carga de gestión y de aspectos económicos y de innovación.

A las demás asignaturas se les ha asignado, de acuerdo con sus coordinadores, un conjunto de competencias genéricas que pueden desarrollar a uno de sus tres niveles, con énfasis en dos de ellas, para las que deberán diseñar actividades formativas específicas que incluyan resultados evaluables. Se establecen así los itinerarios de competencias, por los que cada competencia genérica se imparte y evalúa en un mínimo de dos asignaturas por nivel a lo largo del grado.

IV. CONCLUSIONES

Los nuevos planes de estudios de grado de la ETSETB de la UPC [6], ya verificados por la ANECA y dos de los cuales se han empezado a impartir este curso 2009-2010, tienen una estructura que favorece el aprendizaje de competencias genéricas mediante una fórmula mixta: por una parte éstas se imbrican en todas las asignaturas definiendo itinerarios verticales de competencias y por otra se establecen 3 asignaturas de proyectos, además del TFG, en las que, además de reforzar el aprendizaje de los contenidos de las demás asignaturas, se desarrollan las competencias genéricas de manera natural mediante actividades próximas al ejercicio de la ingeniería. Este esquema cumple con los estándares definidos por la iniciativa CDIO, a la que se ha incorporado la ETSETB en julio de 2009.

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IMPLEMENTATION AND FIRST RESULTS OF THE INTRODUCTION TO ENGINEERING COURSE IN THE ETSETB-UPC NEW DEGREES

Author(s)
Ramon Bragós, Josep Pegueroles, Eduard Alarcón, Adriano Camps, Joan Sardà, Carolina Consolación, Jaume Mussons, Olga Pons, Albert Oliveras, Miguel García, Raúl Onrubia, Elisa Sayrol

Escola Tècnica Superior d'Enginyeria de Telecomunicació, ETSETB-Telecom BCN
Universitat Politècnica de Catalunya, UPC Barcelona
sotsdirinnovacio@etsetb.upc.edu

Abstract - This paper describes the new course "Introduction to ICT Engineering" which has been conceived, designed and implemented at Telecom-BCN (ETSETB-UPC) from initial specifications and restrictions. It is the first of a series of four project subjects distributed throughout the new curricula. It is organized in three parallel paths covering the systemic vision of complex ICT systems, the basic concepts of economics, business and project management and the physical realization of a designbuild project. In the first 5 years, this project is being performed using the SeaPerch platform, a small underwater robot developed at MIT Sea Grant. A payload which includes measurement and communications subsystems is designed and built. After testing with small groups for two semesters, the course will be undertaken with around 250 students in the spring semester of this year.

Keywords - CDIO, design-build experiences, introduction to engineering course

I. INTRODUCCIÓN

En la Escuela Técnica Superior de Ingeniería de Telecomunicación de la Universitat Politècnica de Catalunya (ETSETB-TelecomBCN), se han puesto en marcha cinco nuevos grados. La adaptación al EEES nos permitió llevar a cabo una reorganización en profundidad de los planes de estudio, para lo que se analizaron diversos modelos. De todos ellos, la iniciativa CDIO [1] fue elegida como paradigma. Se diseñaron la estructura de los planes de estudios [2] y la lista y contenidos de las competencias para cumplir con los estándares de CDIO, los establecidos por la UPC y los requeridos por el Ministerio. Para integrar las competencias genéricas en los planes de estudios, se utilizó una aproximación mixta: Por un lado, se asignaron diversas competencias a cada asignatura con el encargo específico de incidir en dos de ellas y evaluarlas, definiendo itinerarios verticales para las competencias genéricas. Por otra parte, se diseñaron cuatro asignaturas específicas de proyectos que se sitúan en el segundo semestre de cada uno de los cuatro cursos. Todas ellas incluyen actividades de diseño e implementación de un sistema complejo. En esta comunicación se describe el diseño, implementación y primeros resultados de la primera de ellas, que se designa por las siglas ENTIC, del catalán "ENginyeria TIC". Todos los contenidos escritos de la asignatura, tanto los suministrados por los profesores como los desarrollados por los alumnos, están en inglés. Para la comunicación oral, se puede escoger el idioma (catalán, castellano o inglés).

Las otras tres asignaturas de proyectos son el Proyecto Básico de Ingeniería (PBE), el Proyecto Avanzado de Ingeniería (PAE) y el Trabajo de Fin de Grado (TFG). Todas ellas se llevan a cabo en el segundo semestre de cada curso. PBE tiene 6 créditos, en el que los estudiantes llevan a cabo el diseño e implementación en grupos (4-6 estudiantes) de un bloque de un sistema complejo a partir de sus especificaciones y conociendo el conjunto del sistema. En PAE, grupos grandes (9-12 estudiantes) levan a cabo el diseño completo de un producto o servicio TIC de complejidad suficiente como para que sea necesario dividirla en 3-4 bloques, incluyendo un plan de empresa. Tiene 12 créditos ECTS a los que se añaden 1,5 créditos adicionales de contenidos de matemáticas coherentes con el proyecto. La temática será específica del grado escogido. TFG (24 créditos) se lleva a cabo individualmente dentro de un departamento o empresa, preferiblemente en otro país.

II. DISEÑO DE LA ASIGNATURA ENTIC

Esta asignatura se llama formalmente "Introducción a la Ingeniería de las TIC" y su diseño ha tenido en cuenta varias especificaciones y restricciones iniciales[3]:

- Como se indica en el estándar 4 de la iniciativa CDIO, es recomendable situar en el primer curso una asignatura de introducción a la ingeniería que proporcione un marco adecuado para la práctica del desarrollo de productos y servicios en ingeniería e introduzca competencias personales e interpersonales básicas.

- Por coherencia con los otros grados similares impartidos en la UPC, debe incluir competencias específicas de economía y empresa. La asignatura pertenece a dicha materia.
- De acuerdo con las recomendaciones de nuestra comisión de plan estratégico y de las comisiones que diseñaron el marco de los grados, se debe introducir la visión de sistema en los productos procesos y servicios desde el primer curso.

Con el fin de alcanzar estos requisitos, hemos organizado la asignatura en tres itinerarios que se realizan en paralelo y están conectados entre sí a través de un tema común. El curso consta de 6 créditos ECTS, que corresponden a una carga para el estudiante de 150 horas a lo largo de 15 semanas. 66 de estas horas se realizan en el aula o laboratorio, con apoyo de profesores y becarios de soporte, mientras que las restantes 84 horas corresponden a trabajo autónomo, tanto a nivel individual como en grupo. Los estudiantes tienen tres sesiones presenciales por semana (dos de 2 horas y una de 1 hora), cada una correspondiente a uno de los itinerarios.

Itinerario 1: Conceptos básicos de conomía y empresa. (2 horas / semana) Aspectos organizativos y económicos del desarrollo de productos y servicios TIC: Introducción a la gestión de proyectos, modelos de negocio TIC, costes e inversiones, herramientas de generación de ideas, marketing, propiedad intelectual e industrial, implicaciones sociales.

Itinerario 2: Visión de sistema. (1 hora / semana) Seis sesiones en las que el profesor expone a los estudiantes la estructura de sistema y los principales aspectos tecnológicos, económicos y sociales de diversos productos TIC complejos. Posteriormente, se lleva a cabo un seminario sobre comunicación oral y escrita y luego cuatro sesiones más en que las que los estudiantes preparan y presentan en público otros productos o servicios TIC distintos de los expuestos por el profesor y son evaluados por los profesores y sus compañeros.

Itinerario 3: Experiencia de diseño implementación. (2 horas / semana) Diseño e implementación de un sistema complejo. Proyecto parcialmente guiado en el que equipos de cuatro estudiantes realizan la implementación de la parte mecánica de un sistema previamente diseñado (por ejemplo un robot) y diseñan e implementan uno o varios subsistemas TIC sobre esta plataforma (medida, control, comunicaciones, ...).

El objetivo principal es: “Entender el contexto de la ingeniería y motivarse para su estudio a través de la exposición a la construcción de sistemas complejos”. Como objetivo secundario, el curso debe contribuir a integrar los conocimientos básicos que los estudiantes ya han aprendido y, sobre todo, provocar la curiosidad por los conceptos que se proporcionan en las asignaturas posteriores.

Como principales resultados del aprendizaje, después de cursar esta asignatura, los estudiantes deben ser capaces de:

- Tener una visión de sistema de los productos TIC
- Describir los principales conceptos y realizar cálculos básicos sobre los aspectos económicos del diseño, producción y comercialización de productos y servicios TIC.
- Llevar a cabo los pasos básicos en la planificación, desarrollo y documentación de proyectos.

También deben haber adquirido los resultados del aprendizaje de varias competencias genéricas. En las asignaturas de proyectos se desarrollan de forma natural la mayor parte de éstas. De todas formas, en el mapa de competencias de los grados, se ha asignado formalmente a esta asignatura la evaluación de cuatro de ellas:

- emprendeduría e innovación
- sostenibilidad y compromiso social
- comunicación oral y escrita
- capacidad para concebir, diseñar, implementar y operar sistemas complejos en el ámbito TIC

Aparte de estas, se trabajan explícitamente las competencias de tercera lengua, trabajo en equipo y uso solvente de los recursos de información. De esta última competencia así como de la de sostenibilidad y compromiso social, los estudiantes reciben 2 y 4 horas de seminarios específicos respectivamente.

III. IMPLEMENTACIÓN DE LA ASIGNATURA ENTIC

El caso de estudio que se ha escogido para estos primeros cinco años es el de un vehículo subacuático con control remoto (ROV) y sus aplicaciones. Los estudiantes se organizan en grupos de 3-4 para la realización de las actividades de los tres itinerarios:

Itinerario 1: Los temas de este itinerario son impartidos por profesores del departamento de Organización de Empresas, especializados en cada uno de los temas y los ejemplos y ejercicios están relacionados con un caso de estudio próximo al tema del proyecto. Además de los aspectos económicos, este itinerario incluye la metodología de gestión y documentación de proyectos. Al final del curso, dos de los estudiantes de cada grupo presentan una idea de negocio basada en el desarrollo del itinerario 3, como elemento de cohesión entre los 3 itinerarios. Como ejemplos, se han presentado diversas ideas de negocio basadas en la comercialización de un kit de robot subacuático para aplicaciones didácticas, para visitas virtuales a parques acuáticos, acuarios e instalaciones similares, para reparación de instalaciones acuáticas, generación de mapas del fondo costero, etc.

Itinerario 2: Los seis temas escogidos para el curso pasado, y de los que se renuevan dos cada cuatrimestre, son los siguientes: el implante coclear, la telefonía móvil, los cables de comunicación submarina, el Voyager, Internet y los satélites de observación de la Tierra. Todos los temas tienen componentes de implementación hardware, procesado, comunicaciones y telemática. En todas las presentaciones se cubren los aspectos siguientes: Background, necesidad del producto, estructura del sistema, breve historia del producto o servicio, modelo de negocio e implicaciones sociales.

Se aprovechan las presentaciones para ir introduciendo conceptos básicos que se explicarán en otras asignaturas (señal/ruido, propagación, respuesta frecuencial, …). Se promueve la participación de los estudiantes en las presentaciones mediante preguntas directas. Antes de cada sesión, los estudiantes deben leer un material relacionado con el tema y contestar a un cuestionario que está disponible en el campus virtual basado en Moodle desde dos días antes. Después de la presentación deben responder a otro cuestionario. El no hacerlo penaliza directamente la nota que obtendrán en su propia presentación a final de curso. En esta presentación, que se lleva a cabo por parte de los dos componentes del equipo que no lo hacen en el itinerario 1, los estudiantes disponen de 15 minutos más 5 de preguntas para cubrir los puntos propuestos sobre un tema TIC no expuesto anteriormente. Su presentación es evaluada por los profesores y compañeros a partir de una rúbrica.

Itinerario 3: Los primeros 5 años, los proyectos se están construyendo alrededor de la plataforma SeaPerch, del MIT Sea Grant Program [4], para lo que la ETSETB ha establecido un convenio con dicha institución. La plataforma es un ROV muy simple. La parte electromecánica del robot se construye con tubos de PVC, motores, cables e interruptores y los estudiantes la concluyen en las primeras 3 sesiones de laboratorio, favoreciendo la consolidación de los equipos de trabajo y el aprendizaje de los conceptos básicos de gestión de tareas. En la figura 1 puede verse el SeaPerch básico, con la estructura, los motores y los interruptores de control.

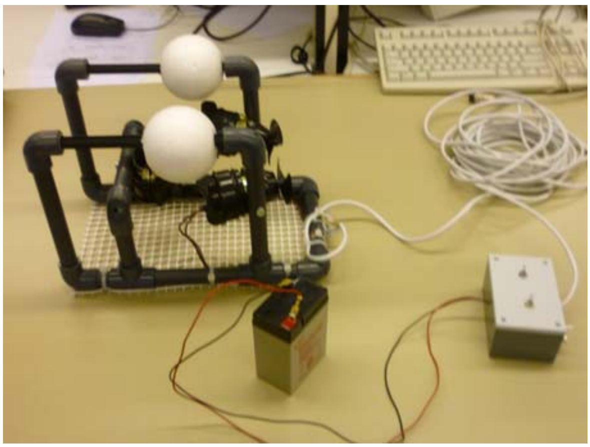

Figura 1: SeaPerch básico, formado por una estructura de PVC y 3 motores de continua controlados mediante interruptores remotos conectados a través de un cable.

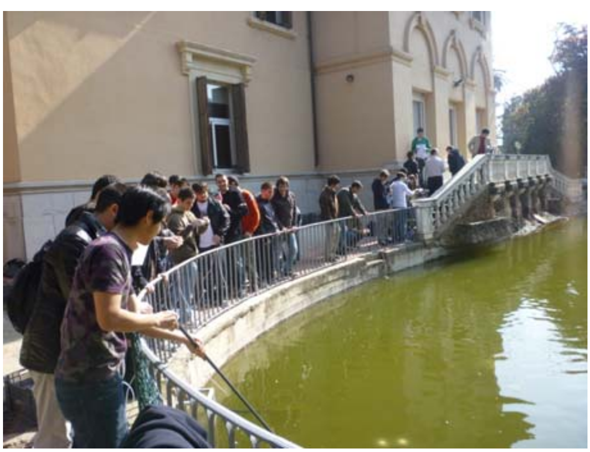

Figura 2: Estudiantes en la prueba de inmersión del SeaPerch, la tercera semana del curso.

Esta parte electromecánica es accesible incluso para estudiantes de secundaria y en el MIT la usan para actividades de extensión universitaria con los institutos de secundaria. La última hora de la tercera sesión, se lleva a cabo una inmersión colectiva (figura 2) que, aparte de resultar motivadora y divertida, establece un hito claro, para la entrega del cual los estudiantes se esfuerzan notablemente.

Pasadas estas tres semanas, los estudiantes se enfrentan al reto de diseñar y construir un determinado payload para el ROV que cambia cada año. Los proyectos previstos incluyen la medición y registro de parámetros del agua (temperatura, profundidad, absorción de luz, conductividad, ...), comunicaciones (RF, ópticas, acústicas), control (gestión de los motores, control de navegación) y las redes de comunicaciones. En el primer y segundo cuatrimestres en que se ha implementado, se ha llevado a cabo la medida de la temperatura del agua en función de la profundidad y la transmisión de la medida de absorción de luz en función de la profundidad respectivamente. El cuatrimestre de primavera de este curso, los estudiantes deben diseñar e implementar un sistema que reconstruya la trayectoria recorrida usando una brújula electrónica (compass sensor). En función de la capacidad de cada grupo, se les pide que añadan prestaciones adicionales al robot.

Los estudiantes llevan a cabo esta asignatura en el segundo semestre de primer curso. Aparte de las primeras asignaturas de matemáticas y física, han cursado una de electrónica básica y una de fundamentos de ordenadores en la que han aprendido programación básica en C. En paralelo, están cursando la continuación de esta última y Circuitos Lineales, aparte de otras asignaturas de matemáticas y física. Por lo tanto, sus conocimientos son limitados pero suficientes para desarrollar pequeños circuitos y programas. En el sistema que deben desarrollar como proyecto, se intenta que se refleje los diversos bloques de un sistema TIC complejo y que se encuentren elementos de los distintos grados impartidos en la ETSETB:

-Se adquieren un mínimo de dos parámetros físicos, con lo que deben conocerse sus principios y los de los sensores que permiten medirlos. Se intenta que uno de los dos responda a un modelo determinista de parámetros conocidos a priori, mientras que el otro necesite de una calibración experimental. Por ejemplo, la determinación de la profundidad a partir de una medida de presión conlleva el conocimiento de la ley que relaciona ambos parámetros, del funcionamiento del sensor (piezoresistivo con conexión en puente de Wheatstone) y del análisis y cálculo de la ganancia del amplificador diferencial que acondiciona su salida. La característica entrada-salida de esta cadena es predecible y se comprueba su validez mediante una calibración llevada a cabo con un manómetro y la regresión lineal de los pares presión-tensión. Se identifican conceptos como los errores de cero y ganancia y la saturación. De la otra variable medida (intensidad de luz, temperatura del agua, …) no hay información a priori y es necesario diseñar un experimento u obtener información adicional para determinar el fondo de escala y la ganancia necesaria. Los estudiantes montan los circuitos primero en placas de prototipos (protoboard, figura 3) y, una vez verificado su funcionamiento los traspasan a una placa de topos que debe caber en la caja estanca en que se sumergirán. Pueden utilizar solamente una alimentación unipolar de 3,3 V, ya que será la única disponible en el sistema sumergible.

- Las señales analógicas se conectan a las entradas de un datalogger comercial que se les proporciona (Logomatic V2 de Sparkfun, en el centro de la figura 3). Este sistema lleva una tarjeta de memoria uSD en la que se graba un archivo de configuración muy sencillo: canales a adquirir de entre los ocho disponibles y frecuencia de muestreo. La tarjeta se alimenta de una pequeña batería de litio-ión-polímero y lleva un regulador que proporciona los 3,3 V de alimentación al circuito construido por los estudiantes. Cuando acaba esta fase, son capaces de tomar medidas de las variables físicas y recuperarlas a posteriori del archivo grabado en la tarjeta. Se identifican conceptos como la evolución del margen dinámico a lo largo de la cadena de medida y la conversión analógico-digital.

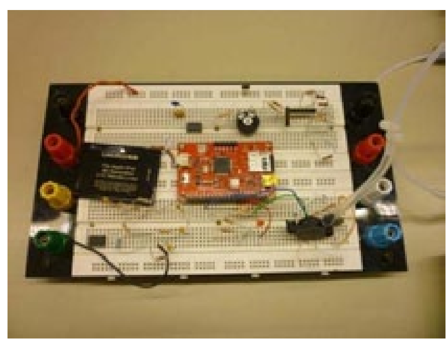

Figura 3: Placa de prototipos con el circuito preliminar y el datalogger (Logomatic V2 de Sparkfun) en el centro.

- En la fase final, se les proporciona una versión modificada del firmware del datalogger que hace accesible la secuencia de bits que se graban en la memoria en uno de los pines del sistema, sin ningún tipo de formato. Los estudiantes deben conseguir que un PC lea estos datos a través de un puerto RS- 232 una vez transmitidos por un par de cables adicionales a los del control de los motores. Esta es la parte de la que tienen menos conocimiento previo. Deben identificar el formato serie en el osciloscopio y modificar una parte acotada del código del datalogger para añadirle bits de start y stop y caracteres de identificación de trama. También deben añadir un circuito adaptador de nivel (MAX3232). Finalmente, con los datos leídos en el PC mediante un programa de terminal, se leen offline utilizando Matlab y se escalan y representan gráficamente utilizando los parámetros de calibración determinados previamente. Se identifica la la calibración por software sin ajustes y la necesidad de un protocolo de comunicaciones a nivel físico y lógico.

- En función de la capacidad de los grupos de trabajo, se les pide que añadan alguna prestación adicional al sistema. Así se han desarrollado sistemas de ajuste de la velocidad de los motores, medidas de parámetros adicionales e incluso una cámara web con un sistema de iluminación LED que se activaba en función de la luz ambiente (figura 4).

Como puede verse, es un conjunto de actividades muy denso, pero hay que tener en cuenta que lo llevan a cabo en equipos de cuatro estudiantes. La división en tareas que puedan ser llevadas a cabo en paralelo es clave para poder acabar el proyecto en el plazo previsto. El diseño parcialmente guiado con hitos en tres puntos del curso ayuda a conseguirlo, aunque hasta ahora ha sido necesario proporcionar sesiones extra al final del curso.

El semestre de primavera del año pasado se cursó esta asignatura con 60 estudiantes, con sólo dos abandonos a principio del curso y se repitió para un grupo pequeño de 16 estudiantes (los que no la habían podido cursar por normativa académica) en este semestre de otoño. El semestre de primavera de este curso entrará en fase de explotación ya que la cursarán alrededor de 250 estudiantes, para lo que se está formando actualmente a 12 nuevos profesores.

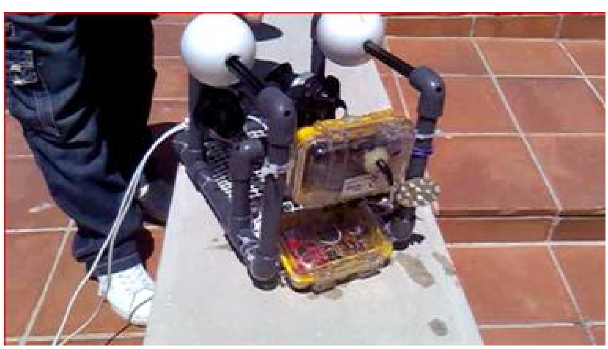

Figura 4: SeaPerch con el circuito de medida y adquisición situado en una caja estanca (abajo) y una ampliación opcional (cámara con sistema de iluminación) en otra caja.

IV. CONCLUSIONES

La organización de la asignatura en tres itinerarios paralelos ha permitido cumplir con las especificaciones y restricciones iniciales. Un tema común actúa como elemento aglutinador y sobre él se lleva a cabo un proyecto parcialmente guiado. Este proyecto parte de un dispositivo electromecánico sencillo, para el que no son necesarios conocimientos específicos y resulta atractivo e incluso divertido y sienta las bases para trazar y seguir un plan de trabajo. En el diseño de los subsistemas TIC básicos se usan conceptos adquiridos en las asignaturas precedentes y concurrentes con ésta y, sobretodo, se hacen evidentes los problemas cuyas soluciones avanzadas se descubrirán en las asignaturas de los siguientes cursos, con lo que se motiva para su estudio. El proyecto permite poner en práctica los conceptos de gestión y documentación de proyectos explicados en el itinerario 1 y que se reforzarán en las siguientes tres asignaturas de proyecto, de complejidad creciente. Como el proyecto de ENTIC está parcialmente guiado, los aspectos económicos son muy simples y no permiten explotar los conceptos explicados en el itinerario 1. Para superar este problema, los estudiantes deben preparar a lo largo del curso una idea de negocio construida alrededor de un ROV (medición de la contaminación, búsqueda arqueológica, ...), y presentarla en público.

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El desarrollo de esta asignatura ha recibido apoyo de la convocatoria de proyectos de innovación docente del ICE de la UPC (2009-2010)

4. Acord MIT SeaPerch-ETSETB

Sea Perch in Spain: ICT-iNEO

An MIT-Telecom BCN/UPC BarcelonaTech collaboration

Prepared for: Dr. Elisa Sayrol (UPC). and Prof. Chryssostomos Chryssostomidis (MIT)
Prepared by: Dr. Eduard Alarcón (UPC) and Dr. Ramon Bragos (UPC)

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Executive Summary

Sea Perch Overview

The Sea Perch Program is a hands-on introductory course in which students design, build and deploy a simple, remotely operated, underwater vehicle (ROV) made from PVC pipe and other readily-available materials. Initially inspired by the book *Build Your Own Underwater Robot and Other Wet Projects*, by Harry Bohm and Vickie Jensen, the Sea Perch Program was established by the MIT Sea Grant College Program in 2003. MIT has brought the Sea Perch Program to over 300 educators in 17 U.S. states and abroad. The program has been used at MIT as an introduction to ocean engineering as well as to undergraduate courses such as "Fundamentals of Engineering Design" as well as "Engineering the Ocean." Sea Perch provides students with an introduction to a wide array of marine science disciplines and technologies and as a result, serves as an inexpensive indirect recruitment tool, reaching a number of scientific disciplines and technologies. This multidisciplinary initiative has for a goal (among others) interesting students in sciences while making them aware of environmental issues. In the process of building the Sea Perch, a multi-disciplinary endeavor, students learn principles of design, principles of underwater communication, scientific measurement and analysis, sensor development, water proofing, electrical wiring and circuit assembly, mapping, sampling, and much more.

Our objective is to introduce the Sea Perch program to Spain. The program embodies strong educational concepts that need promoting in Spanish universities. We propose to initiate a pilot project for a few years that will serve as the foundation for more ambitious and far-reaching projects in the near future. The envisioned project consists of collaboration between the Massachusetts Institute of Technology (MIT) in Cambridge (USA) and the School of Telecom Engineering (Telecom BCN) at the Universitat Politècnica de Catalunya (UPC) Barcelona Tech (Spain). The initial effort will include the creation of a course closely related to the Sea Perch program for first year bachelor of engineering undergraduate students at Telecom BCN-UPC. This interdisciplinary course will be offered starting as a preliminary pilot project for a reduced set of students in February 2011 (second semester of the 2009-2011 academic year) and will include the building of the Sea Perch ROV as well as more theoretical lectures, including engineering materials in EE System engineering.

Objectives

Long-term goals

The objective is to bring the Sea Perch program, or some version of the program, to Spain. The creation and implementation of a strong program in Spain will require the following:

- The educational aspects should involve universities and engineering schools interested in integrating the program into their curriculum.
- The Sea Perch could be used as an educational tool to foster interest in complex engineering systems. With a wider perspective, the Sea Perch platform could be instrumental to create awareness regarding ecology and bio-diversity in aquatic and marine environments.
- Finally, it would be desirable that Spanish R&D laboratories connected to universities and to industry be encouraged by various interactions to develop tools and technologies associated with the Sea Perch.

While it is obvious that the Sea Perch program can serve many purposes, for the time being, this proposal will discuss mainly non-profit educational aspects.

Short-term goals

The point of this proposal is to initiate a pilot project for three years that will serve as the foundation for more ambitious and far-reaching projects. The envisioned project consists of collaboration between MIT and Telecom BCN-UPC. MIT and Telecom BCN-UPC will work together to create and develop a Sea Perch educational program at Telecom BCN-UPC. The project will benefit from the steady support and experience of MIT Sea Grant Program, the initiator of the project in the USA, both at the technological and organizational levels Telecom BCN-UPC will work on adapting the program to the Spanish educational environment and will collaborate with MIT to define the scientific topics covered in this program and develop the corresponding texts and materials.

- We propose a core course on Introduction to ICT Engineering as part of the Electrical and Telecom Engineering curricula for first year undergraduate students at Telecom BCN-UPC. This interdisciplinary course will include (a) the Sea Perch robot building and testing, customized and extended to include educational electronics modules for data logging, communications and network operation, concurrently with

(b) a track devoted to a seminar series on representative complex ICT systems, and (c) a track devoted to management and economics aspects. The course crystallizes in proposing a business idea based on applications of the Sea Perch platform to practical problems.

- After the first year, we intend to invite other UPC Schools, including the Schools of Civil, Industrial, Informatics and Naval Engineering, to consider Sea Perch for educational purposes. Other universities or institutions in Spain could also participate in this project. Telecom BCN will work on disseminate the educational benefits of the Sea Perch program.

Project description

Education at Telecom BCN-UPC

UPC is the largest Engineering University in Spain, with 10 Campuses, 40 Departments, 194 Research groups and centers, 28,887 Graduate and undergraduate students, 1,858 Master's degree students, 2,912 Doctoral students, 4,550 Students on continuing education programs, 4,370 Graduate and undergraduate degrees awarded (academic year 2007/08), 237 Doctoral degrees awarded (academic year 2007-08), 3,575 Students on educational cooperation programs in companies, 1,768 Students on international student exchange programs, 1,090 Sent students, 678 Received students, 3,555 Graduate and Undergraduate students with scholarships, 253 Doctoral students on a scholarship, 2,713 Faculty and research staff, 1,584 Administrative staff, and funding of € 74,379,624.54 Income from research, development and innovation projects (year 2008). UPC offers 78 Graduate and Undergraduate official degrees, 10 internal Double degrees, 96 Double degree international programs, 58 Master's programs 2009-10 (7 Erasmus Mundus and 15 taught in English), 47 Doctoral programs (31 meeting criteria of excellence). UPC is Spain's technical university with (a) the highest number of international doctoral students (b) the highest ratio of PhD graduates (c) the highest scientific production (d) the highest research competitiveness (number of approved R&D projects/number of applications) and highest research income (number of approved R&D projects/number of UPC faculty members) (e) the highest research income from the Spanish National Science Foundation (research income/faculty members) (f) the highest income from research projects (g) the highest number of master's degree students from abroad (h) the highest citable output in the fields of Computer Science and IT; Mechanical; Naval and Aeronautical Engineering; Civil Engineering and Architecture; Electrical and Electronic Engineering and Automatic Control; and Electronic and Communications Technologies in the SCImago Research Group Ranking of IberoAmerican Institutions (i) the highest research income from the European Union VI Framework Program (2002-2006). UPC, jointly with University of Barcelona was recently awarded the top best "campus of excellence" within a nation-wide ranking of Universities.

Within UPC, Telecom BCN is one of the largest engineering Schools, with 1900 students, 285 faculty members, 10 research departments involved, 36 educational labs, 310 students graduated per year -132 of which with an international stay and 50% with a coop in companies-. The School has 16 Double degree agreements, 100 mobility agreements, and 470 coop agreements with companies.

ENTIC- Undergraduate course for freshmen students in Telecom Engineering

At Telecom BCN, we started the design of the new curricula into the frame of the European Higher Education Area (Bologna process) in 2007. Five new bachelor degrees (4 year) have been designed. Two of them (Audiovisual Systems Engineering and Electronics Systems Engineering) have already started their courses in the 2009-2010 academic year. The remaining three (Communication Systems Engineering, Networks, Telecom Science and Technology) will start in September 2010.

The adaptation to the Bologna process allowed us to perform an in-depth reorganization, so that CDIO was chosen as a paradigm for new curricula design. The learning outcomes were identified; the skills and abilities list was defined and developed by matching our University standards with the CDIO Syllabus and the curricula structure was established. We used a mixed approximation to integrate CDIO skills into the curriculum: On the one hand, the skills pathways were defined by involving all courses. Every subject may contribute to the learning of several skills at a given level (1 to 3) and should actively contribute to develop and assess two of them. On the other hand, four specific project courses have been scattered along the curricula, at the second semester of each academic year. They all include design-build activities and put emphasis on CDIO Syllabus fourth group of skills.

We propose to introduce the Sea Perch program at Telecom BCN-UPC through a core course for first year undergraduate students, called ENTIC. This course will be proposed as part of the Telecom Engineering curriculum.

ENTIC Practical setup and syllabus draft

This course is formally called "Introduction to ICT Engineering" and its design has taken into account several initial specifications and restrictions. As stated in the 4th CDIO standard, it should provide the framework for engineering practice in product and system building, and introduce essential personal and interpersonal skills. Being a first-year, course and due to our University regulations, it should include basic economics topics. According to the recommendation of our strategic plan committee, it should introduce the system view in engineering products, processes and services. In order to achieve these requirements, we organized the subject in three parallel tracks, connecting them with a common topic. The course has 6 ECTS credits, which corresponds to a student load of 150 hours along 15 weeks. 66 of these hours are performed in classroom or laboratory with lecturer support, whilst the remaining 84 hours correspond to autonomous work, both individual and group work.

The students have 3 sessions per week (two with 2 hours and one with 1 hour), each one corresponding to one track, plus the autonomous work:

- Track 1: Basic economics. (2 hours/week) Organizational and economics aspects of product development: Introduction to project management, ICT business models, product development economics.

- Track 2: System view. (1 hour/week) Five sessions in which the lecturer exposes the students to face system structure and main technological and economical aspects of complex ICT related products (Internet, cell phone, GPS, ...). Subsequently, a seminar on oral and written communication follows, and then five more sessions in which the students perform cooperative work preparing and presenting additional ICT products or services.

- Track 3: Design-implement experience. (2 hours/week) Development of a partially guided project in which the student teams perform the implementation of the mechanical part of an already designed system (e.g. a robot) and the design and implementation of an ICT subsystem (electronics, control, communications, ...).

The plan for the following years focuses on projects to be built around the Sea Perch platform. The mechanical part of the underwater robot can be built in the first 2-3 sessions, favoring the consolidation of the work teams. Afterwards the students face the challenge of designing and building a specific ROV payload that changes every year. The foreseen projects include measurement and data logging of water parameters (temperature, depth, light absorbance, conductivity), communication (RF, optical, acoustical), control (efficient motor driving, computer control of navigation) and networks. This first introductory year we will start with measurement of water temperature and depth (through pressure) and a very simple optical communication system. This project allows starting with a simple mechanical device which will be appealing and even fun. The students' performance will not depend upon their previous knowledge but upon their ability on following a plan. The design of the basic ICT-related subsystems will make apparent problems whose advanced solutions will be discovered in the following courses of the curriculum. The whole project will allow putting in practice the project management concepts explained in track 1 and which will be reinforced in the following 3 project subjects, whose complexity and degrees of freedom grow year by year. Being a partially guided project, the economic aspects are very simple and do not allow to exploit the concepts explained in track 1. To overcome this problem, the students should prepare along the course a basic business plan built around a ROV and present it in public.

Project organization

Below are the main components of the effort for each year. Both MIT and Telecom BCN-UPC contributions are itemized.

YEAR 1

Preparation for Program Initiation and Curriculum Development

The following preparations will be made by Telecom BCN-UPC and will be completed by the end of 2010:

- 1. Manual Development
  - ✓ Telecom BCN-UPC will create a manual that is specific to the needs of the Telecom BCN-UPC program. This construction manual will allow users to build a Sea Perch according to specifications and the course curriculum. This manual can be spread to other Universities in Spain, as well as High School for Outreach purposes.
- 2. Parts List and Supplier Identification
  - ✓ Telecom BCN-UPC will contact identify the best suppliers (according to MIT criteria) in order to check prices and availability of the parts and tools needed.
- 3.Curriculum Development
  - ✓ Telecom BCN-UPC will be in charge of developing the curriculum. Telecom BCN-UPC will blend and connect different engineering topics including mechanical engineering, ocean engineering and, specifically, electrical engineering/electronics to make it an interdisciplinary curriculum. Telecom BCN-UPC will provide appropriate lecture notes, homework and exams to the students.

In all the previous items, Telecom BCN UPC will share all the information with MIT so as to receive their suggestions and approval. Particularly, Telecom BCN UPC will share detailed information about the extension of the Sea Perch platform to include enhanced functionality in terms of electronics, communication and network aspects.

In-Person Support

If of interest to MIT staff, Telecom BCN UPC will fund visits from MIT colleagues to ensure appropriate evolution of the Sea Perch project. If agreed, MIT staff will participate in the Sea Perch robot competition assessing committee, while UPC will coordinate the capstone event at the end of the program including logistics, facilities, and proper media coverage for the event.

Online Support

Telecom BCN-UPC will be in charge of developing a Spanish Telecom BCN-UPC Sea Perch-centric web page that links to the MIT Sea Perch website.

Teaching

Telecom BCN-UPC staff will teach the entire class (theoretical classroom material + construction of the robot) to the ENTIC students.

External lecturers

External partners will be allowed to present their activities and give some lectures with the acquaintance of MIT-Telecom BCN-UPC.

YEAR 2

Developments

- ✓ Telecom BCN-UPC will create a detailed curriculum that will have more intensive coursework than year one, and relate more directly to the Electrical engineering field.

- ✓ Telecom BCN-UPC will investigate the possibility of extending the Sea Perch in Industrial Engineering, Marine, Nautical, biological research in Telecom BCN-UPC satellite campuses.

YEAR 3

Developments

- ✓ Telecom BCN-UPC will fully deploy the Sea Perch initiative

Potential impact and future developments at Telecom BCN-UPC

Impact at Telecom BCN-UPC

This program is innovative for Telecom BCN-UPC not only because it is a multidisciplinary approach but also because it combines a theoretical approach with hands-on experience. Feedback on the concept from Telecom BCN-UPC staff we contacted has been very favorable, which bodes well for the program's success. The Sea Perch ROV itself will appeal to the students as it shows that a lot can be achieved with modest means. Further, it has a very slight impact on the natural environment due to its small size. Finally, it is inexpensive (made mostly of PVC) and non-polluting (electrical propulsion). Our multidisciplinary approach will motivate and engage students. We can envision that in coming years, third year students at Telecom BCN-UPC who have taken this class, in our degrees on Electronic Systems, Audio/Video Engineering, Communications, and Networking, will show enhanced engineering skills. Moreover, this kind of project should encourage students to apply for internships in industry and to pursue scientific careers after graduation.

Public awareness

We plan to foster outreach activities and media visibility around the use of the Sea Perch platform.

This program and the proposed course are multidisciplinary and involve several disciplines (mechanical engineering, robotics, ocean engineering, electrical and telecom engineering). Nevertheless, because it is built around a small underwater robot, it is perceived by the public as being an exploration tool capable of monitoring and measuring marine ecosystems and its biodiversity. Biodiversity observation is fundamental for the preservation of aquatic natural habitats, fauna and flora. Moreover, because the students build their own robots, they show that they can become actors in understanding and protecting natural resources with a modest but capable tool and in-depth scientific knowledge and awareness. They will understand that their approach must be global and involve many disciplines if they want to understand and protect the complexity of nature mechanisms.

Contact information

Coordinates of the Telecom BCN - UPC contacts:

Dr. Elisa Sayrol
Dean
School of Telecom Engineering – Telecom BCN
Building B3, Campus Nord UPC
UPC BarcelonaTech
Jordi Girona, 1-3
08034 Barcelona, Spain
directora@etsetb.upc.edu
Telf: (34) (93) 401 68 32
FAX: (34) (93) 401 68 01

Coordinates of the MIT contact:

Prof. Chryssostomos Chryssostomidis
Director, Sea Grant College Program
Doherty Professor of Ocean Science and Engineering
Massachusetts Institute of Technology (MIT)
77 Massachusetts Avenue, E38-300
Cambridge, MA 02139
Tel +1617253-7131
chrys@mit.edu
http://web.mit.edu/seagrant/edu/seaperch/

The undersigned agree to the terms of the collaboration described above:

NOV 12 2010

Dr. Elisa Sayrol **Date**
Dean
School of Telecom Engineering – Telecom BCN
UPC BarcelonaTech

OCT 28 2010

Prof. Chryssostomos Chryssostomidis **Date**
Director, Sea Grant College Program
Doherty Professor of Ocean Science and Engineering
Massachusetts Institute of Technology (MIT)

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5. CDIO STANDARDS

TELECOM-BCN PROGRAM SELF-EVALUATION ACCORDING TO THE CDIO STANDARDS

BACKGROUND

The CDIO Initiative creates a range of resources that can be adapted and implemented by individual programs to meet these goals. These resources support a curriculum organized around mutually supporting disciplines, interwoven with learning experiences related to personal and interpersonal skills, and product, process and system building skills. Students receive an education rich in design-implement experiences and active and experiential learning, set in both the classroom and other learning workspaces. The two main resources are the CDIO Syllabus, according to which the different programs define or revise their own competences set, and the CDIO Standards, which establish a framework for program reform and evaluation[1]. In January 2004, the CDIO Initiative adopted 12 standards to describe CDIO programs. These guiding principles were developed in response to program leaders, alumni, and industrial partners who wanted to know how they would recognize CDIO programs and their graduates. As a result, these CDIO Standards define the distinguishing features of a CDIO program, serve as guidelines for educational program reform and evaluation, create benchmarks and goals with worldwide application, and provide a framework for continuous improvement. The standards may also be used as a framework for certification purposes.

The 12 CDIO Standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-implement experiences and workspaces (Standards 5 and 6), methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12).

The assessment of compliance with the CDIO Standards is a self-reported process. An engineering program gathers its own evidence and uses the rubrics to rate its status with

[1] Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. "Rethinking engineering education: the CDIO approach". Springer, 2007.

respect to each of the 12 CDIO Standards. All programs that have become members of the CDIO collaborative are automatically ***Collaborators***. In order to remain as a collaborator, a program must continue to be involved with the CDIO Initiative, by attending meetings, and reporting on its progress, and must periodically report on its selfevaluation. This status is unchanged from existing policy. An ***Implementer*** has developed a program self-evaluation that shows that it has reached a rating of 2 or higher on the required Standards (1, 2, 3, 5, 7, 9, and 11). The final stage, ***Certified Program***, requires a rating of ***4*** or higher on the required Standards (1, 2, 3, 5, 7, 9, and 11), and a rating of 2 or higher on the other Standards (4, 6, 8, 10, and 12).

Telecom-BCN program self-evaluation at July 2011

#	Standard	Mark (scale 0-5)
Standard 1	The Context	3
Standard 2	Learning Outcomes	3
Standard 3	Integrated Curriculum	3
Standard 4	Introduction to Engineering	3.5
Standard 5	Design-Implement Experiences	3
Standard 6	Engineering Workspaces	2,5
Standard 7	Integrated Learning Experiences	2,5
Standard 8	Active Learning	2,5
Standard 9	Enhancement of Faculty Competence	2
Standard 10	Enhancement of Faculty Teaching Competence	2
Standard 11	Learning Assessment	2
Standard 12	Program Evaluation	2

Standard 1 – The Context

Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education

Rubric:

Scale	Criteria
5	Evaluation groups recognize that CDIO is the context of the engineering program and use this principle as a guide for continuous improvement.
4	There is documented evidence that the CDIO principle is the context of the engineering program and is fully implemented.
3	CDIO is adopted as the context for the engineering program and is implemented in one or more years of the program.
2	There is an explicit plan to transition to a CDIO context for the engineering program.
1	The need to adopt the principle that CDIO is the context of engineering education is recognized and a process to address it has been initiated.
0	There is no plan to adopt the principle that CDIO is the context of engineering education for the program.

Evidences:

- There is general agreement among faculty members that the CDIO principle is desirable as a basis for program renewal.
- We have initiated a faculty orientation to CDIO through participation in CDIO meetings and the Introductory CDIO Workshop.
- The academic council has approved a new curriculum plan based on CDIO principles.

Standard 2 – Learning Outcomes

Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders

Rubric:

Scale	Criteria
5	Internal and external groups regularly review and revise program learning outcomes, based on changes in stakeholder needs.
4	Program learning outcomes are aligned with institutional vision and mission, and levels of proficiency are set for each outcome.
3	Program learning outcomes are validated with key program stakeholders, including faculty, students, alumni, and industry representatives.
2	A plan to incorporate explicit statements of program learning outcomes is accepted by program leaders, engineering faculty, and other stakeholders.
1	The need to create or modify program learning outcomes is recognized and such a process has been initiated.
0	There are no explicit program learning outcomes that cover knowledge, personal and interpersonal skills, and product, process and system building skills.

Evidences:

- We recognize the need to specify outcomes for our new education model.
- We defined the learning outcomes in our programs consistent with CDIO and the Bologna process.
- The detailed CDIO Syllabus was customized for the institution's context. The generic skills learning outcomes defined by the UPC have been mapped with the CDIO Syllabus definitions and learning outcomes and three additional Telecom- BCN generic skills have been defined to overcome the initial list lacks.
- The generic skills learning outcomes have been defined with three depth levels.
- The CDIO Syllabus has been validated with program stakeholders.
- Learning outcomes are aligned with our institutional mission and with national accreditation criteria.

Standard 3 – Integrated Curriculum

A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills

Rubric:

Scale	Criteria
5	Internal and external stakeholders regularly review the integrated curriculum and make recommendations and adjustments as needed.
4	There is evidence that personal, interpersonal, product, process, and system building skills are addressed in all courses responsible for their implementation.
3	Personal, interpersonal, product, process, and system building skills are integrated into one or more years in the curriculum.
2	A curriculum plan that integrates disciplinary learning, personal, interpersonal, product, process, and system building skills is approved by appropriate groups.
1	The need to analyze the curriculum is recognized and initial mapping of disciplinary and skills learning outcomes is underway.
0	There is no integration of skills or mutually supporting disciplines in the program.

Evidences:

- We have held workshops to examine the curriculum and the intended program outcomes.
- We have performed a mapping of personal, interpersonal and system building related learning outcomes onto the curriculum.
- The curriculum design is complete and has been approved at all levels.
- Every course has a plan outlining the skills that should be integrated, as well as the degree of implementation.
- A set of project courses has been defined. A framework for integrating personal, interpersonal and system building skills is found in the sequence of project courses.
- The new curricula have been implemented up to the 2nd year.

Standard 4 – Introduction to Engineering

An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills

Rubric:

Scale	Criteria
5	The introductory course is regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the introductory engineering course.
3	An introductory course that includes engineering learning experiences and introduces essential personal and interpersonal skills has been implemented.
2	A plan for an introductory engineering course introducing a framework for practice has been approved.
1	The need for an introductory course that provides the framework for engineering practice is recognized and a process to address that need has been initiated.
0	There is no introductory engineering course that provides a framework for practice and introduces key skills.

Evidences:

- We have defined an introductory course that includes a project in all our degree programs.
- An introductory engineering course has been implemented in a pilot group (60 students) in the academic year 2009-2010, with the goals of introducing the role of the engineer, written and oral communication, and the use of the project model.
- Our first-year "Introduction to ICT Engineering" course has been fully implemented in all our degrees (240 students) in the academic year 2010-2011.
- Our first-year course is documented and evaluated yearly by students and instructors, guiding necessary improvements.

Standard 5 – Design-Implement Experiences

A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level

Rubric:

Scale	Criteria
5	The design-implement experiences are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the design-implement experiences.
3	At least two design-implement experiences of increasing complexity are being implemented.
2	There is a plan to develop a design-implement experience at a basic and advanced level.
1	A needs analysis has been conducted to identify opportunities to include design-implement experiences in the curriculum.
0	There are no design-implement experiences in the engineering program.

Evidences:

- We now have a basic design-implement experience in Year 1, included in the "Introduction to Engineering course"
- An intermediate design-implement-test experience in Year 2 has been offered and followed by a 24 students pilot group
- An advanced conceive-design-implement-test experience is planned for Year 3 in the following academic year.

Standard 6 – Engineering Workspaces

Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning

Rubric:

Scale	Criteria
5	Internal and external groups regularly evaluate the impact and effectiveness of workspaces on learning and provide recommendations for improving them.
4	Engineering workspaces fully support all components of hands-on, knowledge, and skills learning.
3	Plans are being implemented and some new or remodeled spaces are in use.
2	Plans to remodel or build additional engineering workspaces have been approved by the appropriate bodies.
1	The need for engineering workspaces to support hands-on, knowledge, and skills activities is recognized and a process to address the need has been initiated.
0	Engineering workspaces are inadequate or inappropriate to support and encourage hands-on skills, knowledge, and social learning.

Evidences:

- Workspaces existed in limited quantity in the labs. Suitable spaces were identified and assigned to project subjects.
- A set of four labs was adapted and a room was refurbished to store the students projects.
- A small mechanical workshop was added to the existing electrical labs to allow the project implementation.
- The organization of the labs was adapted to allow students free access.
- The structure of the classrooms was adapted to allow flexible class modalities into a general campus improvement plan.
- More small-group meeting rooms are planned.

Standard 7 – Integrated Learning Experiences

Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills

Rubric:

Scale	Criteria
5	Courses are regularly evaluated and revised regarding their integration of learning outcomes and activities.
4	There is evidence of the impact of integrated learning experiences across the curriculum.
3	Integrated learning experiences are implemented in courses across the curriculum.
2	Course plans with learning outcomes and activities that integrate personal and interpersonal skills with disciplinary knowledge has been approved.
1	Course plans have been benchmarked with respect to the integrated curriculum plan.
0	There is no evidence of integrated learning of disciplines and skills.

Evidences:

- All course plans include learning outcomes that address personal and interpersonal skills assigned to them in the curriculum plan. At least two generic skills are promoted in every course at a given level (basic-middle-high).
- The course coordinators have been asked to design at least two learning activities that could be used to assess the learning outcomes of the generic skills.
- Periodic meetings (two per semester) are being performed to gather the performance of these experiences.
- Intensive integrated learning in found in project courses, where all generic skills are promoted and at least four of them are assessed.

Standard 8 – Active Learning

Teaching and learning based on active experiential learning methods

Rubric:

Scale	Criteria
5	Internal and external groups regularly review the impact of active learning methods and make recommendations for continuous improvement.
4	There is documented evidence of the impact of active learning methods on student learning.
3	Active learning methods are being implemented across the curriculum.
2	There is a plan to include active learning methods in courses across the curriculum.
1	There is an awareness of the benefits of active learning, and benchmarking of active learning methods in the curriculum is in process.
0	There is no evidence of active experiential learning methods.

Evidences:

- Active, self-instructed, competency-based learning is one of the action items in the educational development plan of our university.
- A number of active learning experiences exist in lab courses.
- Faculties are encouraged to include active learning experiences in their courses. Periodic meetings (two per semester) are being performed to gather the performance of these experiences and share the results.
- A mentoring system is in place to help students develop good study habits.
- Three design-build project courses have been designed (two of them heve already been implemented) which intensively use active learning.
- More focus needs to be put on this standard.

Standard 9 – Enhancement of Faculty Competence

Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills

Rubric:

Scale	Criteria
5	Faculty competence in personal, interpersonal, product, process, and system building skills is regularly evaluated and updated where appropriate.
4	There is evidence that the collective faculty is competent in personal, interpersonal, product, process, and system building skills.
3	The collective faculty participates in faculty development in personal, interpersonal, product, process, and system building skills.
2	There is a systematic plan of faculty development in personal, interpersonal, product, process, and system building skills.
1	A benchmarking study and needs analysis of faculty competence has been conducted.
0	There are no programs or practices to enhance faculty competence in personal, interpersonal, product, process, and system building skills.

Evidences:

• Currently, the faculty competence relies on the university's teacher development program. New lecturers follow an initial training program. There is no mandatory training for faculties with permanent position.

• Several of the university's teacher development program courses are centered on teaching competences in personal and interpersonal skills.

• An internal peer-instruction plan has been designed to train the faculties involved in project subjects. There is a three subject path of increasing complexity. Additionally to a 12 hours initial course, every new faculty should enter the path by the lowest level (Introduction to Engineering course) and share the students group with a more experienced colleague. From the initial 4 lecturers group, 12 more faculties have been trained this last academic year and 6 more are going to join the team the following semester.

Standard 10 – Enhancement of Faculty Teaching Competence

Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning

Rubric:

Scale	Criteria
5	Faculty competence in teaching, learning, and assessment methods is regularly evaluated and updated where appropriate.
4	There is evidence that the collective faculty is competent in teaching, learning, and assessment methods.
3	Faculty members participate in faculty development in teaching, learning, and assessment methods.
2	There is a systematic plan of faculty development in teaching, learning, and assessment methods.
1	A benchmarking study and needs analysis of faculty teaching competence has been conducted.
0	There are no programs or practices to enhance faculty teaching competence.

Evidences:

- Currently, the faculty competence relies on the university's teacher development program. New lecturers follow an initial training program. There is no mandatory training for faculties with permanent position.
- Teacher's development courses are encouraged. The amount of courses received by faculties has doubled in the last three years.
- Short development courses are tailored and promoted by the three engineering schools in the Campus.
- We realize that new training programs need to be launched by the university's educational and staff development department.

Standard 11 – Learning Assessment

Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge

Rubric:

Scale	Criteria
5	Internal and external groups regularly review the use of learning assessment methods and make recommendations for continuous improvement.
4	Learning assessment methods are used effectively in courses across the curriculum.
3	Learning assessment methods are implemented across the curriculum.
2	There is a plan to incorporate learning assessment methods across the curriculum.
1	The need for the improvement of learning assessment methods is recognized and benchmarking of their current use is in process.
0	Learning assessment methods are inadequate or inappropriate.

Evidences:

- Currently, the faculty competence relies on the university's teacher development program. New lecturers follow an initial training program. There is no mandatory training for faculties with permanent position.
- Short development courses are tailored and promoted by the three engineering schools in the Campus. Several of them emphasize the learning assessment.
- A specific model for project learning outcomes assessment is under discussion in the project-subjects faculty team.

Standard 12 – Program Evaluation

A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

Rubric:

5	Systematic and continuous improvement is based on program evaluation results from multiple sources and gathered by multiple methods.
4	Program evaluation methods are being used effectively with all stakeholder groups.
3	Program evaluation methods are being implemented across the program to gather data from students, faculty, program leaders, alumni, and other stakeholders.
2	A program evaluation plan exists.
1	The need for program evaluation is recognized and benchmarking of evaluation methods is in process.
0	Program evaluation is inadequate or inconsistent.

Evidences:

- The programs are subject to the national evaluation process. The involvement in the CDIO model was described in the definition of the new degrees so it will be evaluated.
- The programs are also involved in a quality assurance program defined by the Catalan University Quality Agency (AQU) and driven by our University. The AUDIT program defines a mandatory structure of 6 main lines and 16 secondlevel lines. Given that we have the need to align this quality assurance plan with the CDIO standards, we mapped the standards with the AUDIT lines and included basic definitions in the 230.1.2.2.2 point (teaching development). We plan to enhance this point in following revisions.
- We are designing a web questionnaire to gather competence learning outcomes from employers.

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