Proposed framework for Transdisciplinary Product and Process Design Education

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ABSTRACT

Breakthrough products and services (e.g., iPhone, YouTube, Facebook) show us that products must do more than just “do the job”. They must “do the job” in an overwhelming, industry transforming way to overtake competitors. What can we learn from these successes and how could this change the way we teach our students? How can students be prepared to take an active part in the creation of the next breakthrough products and services in industry?

In this paper, we describe an initiative to create a transdisciplinary project learning environment by growing on many interdisciplinary experiences and building on previous multidisciplinary successes like MATI Montréal research-transfer center (www.matimtl.ca). It regroups three institutions in engineering, education and business to develop and study the use of technology in education. MATI houses an innovative ideation support systems lab called the Hybrid Ideation Space [1]. The proposed transdisciplinary framework will be part of MATI’s strategic objectives, under its collaborative product and process design initiative.

The proposed framework will:
1) Cultivate the design and innovation abilities of students in complex and realistic industry mentored projects.
2) Make students experiment the divergent points of view and expertise from different specialists involved in industrial product development.
3) Make students participate in the complete product development and production cycle multiple times. Develop a holistic view of project issues and impacts.
4) Build international academic relations so students can have true multinational, transdisciplinary project experiences.
5) Use the projects as a basis for design methodology and tools research to improve the project framework and transfer new acquired knowledge to industry.

KEYWORDS

Transdisciplinarity, complex projects, collaboration with industry, open ended problems.

TRANSFORMATION OF DESIGN PROJECTS IN INDUSTRY

Outsourcing has changed the industrial environment where students will work. Manufacturing knowledge and technical design expertise are no longer captive abilities as they are now transferred to independent suppliers. The difficulty is no longer how we can make a product, it has become what product should we be making. Successful new products and services provide solutions to very complex design problems to answer human needs. To achieve a virtually seamless product experience, design staff must constantly cross disciplinary boundaries.

“The user experience has to go through the whole end-to-end system, whether it’s desktop publishing or iTunes. It is all part of the end-to-end system. It is also the manufacturing. The supply chain. The marketing. The stores. “

John Sculley, ex-CEO Apple Computers

The product is no longer just a physical artefact. It has become a stream of intertwined experiences: brand image, interaction, communication, sharing, and content; each small part contributing to the success of the whole. Solving complex problems of this type requires the combination of many fields of expertise and is based on profound and integrated systems knowledge. This knowledge can come from many years of experience of one individual but can also come from a very efficient open collaboration between specialists. This collaboration extends far beyond the traditional engineering domain. The level of collaboration required is also far beyond working punctually with external collaborators from other disciplines. The level required is true transdisciplinary collaboration.

TRANSDISCIPLINARITY IN DESIGN EFFORTS

Complex “wicked” [2] problems do not only need to be solved but solutions must ensure long term sustainability of design choices. The problem solving approach needed to resolve complex issues must provide a wider view than what standard disciplinary problem solving methods offer. “Transdisciplinarity raises the question of not only problem solution but problem choice” [3]. The design solutions can no longer just be the result of standard technical problem solving but must take a much larger view including impact on society and ethical questions. Fundamental questions like : what to design, what not to design, why should we design this specific product and not another, what long term impact might this product have, is this impact justifiable, does this product only contribute to consumerism and finally can we design differently ? Students doing project work must be exposed as early as possible to these complex questions so they can prepare to answer them or be ready to transform the problem (the question) to get better solutions (answers).

Transdisciplinary projects can be differentiated from inter- or multidisciplinary efforts by a few features: “problem focus, evolving methodology and collaboration” [4], as detailed in Table 1.

Table 1
Transdisciplinary approach, taken from [4]

Features	Characteristics
Problem focus	▪ Explicit intent to solve complex and multidimensional problems. ▪ Involves interface between humans and systems. ▪ Transdisciplinary problems are in the world and actual instead of in my head and conceptual.

Evolving methodology	▪ Transdisciplinary work develops a common methodology that integrates different disciplinary methodologies into one.
Collaboration	▪ Collaborative knowledge generation between project team, people affected by the project and all stakeholders.

TRANSDISCIPLINARY PROJECT FRAMEWORK

Different avenues have been used to foster collaborative work between product development disciplines in an academic context. Engineering CDIO projects, multidisciplinary projects inside and between schools, multidisciplinary curriculum to train “super designers” all include a push toward collaboration. Stanford University’s d.school, Aalto University and the upcoming EIT ICT labs are prime examples of the drive towards even greater collaboration between disciplines involved in product and process development.

Since 1999, École Polytechnique has engineering student capstone projects with the aerospace industry (CAMAQ projects) [5] and shown in Figure 2. Participating in the CDIO initiative has brought curriculum changes to extend this type of project. The goal is that students in all engineering disciplines will complete four projects covering all aspects of the design-build-implement-operate cycle.

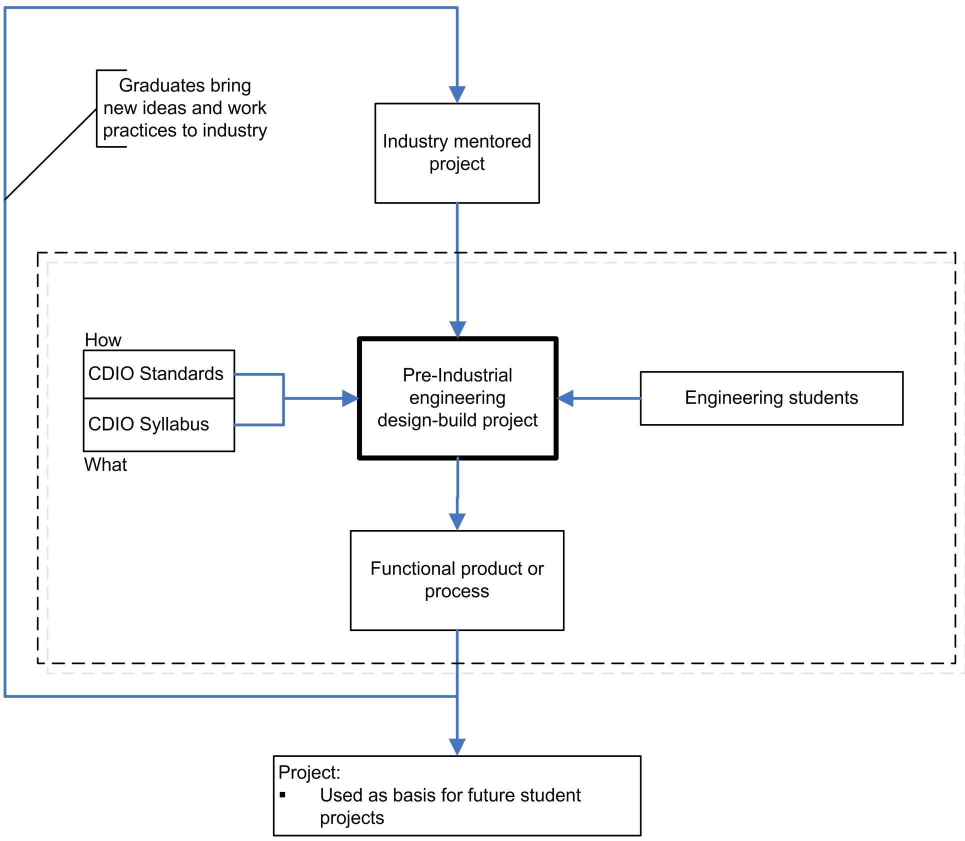

Figure 2. CAMAQ framework

To further improve this project vision, multidisciplinary projects were introduced in 2006 to integrate engineering students to collaborative teams including students from outside of engineering disciplines to work on a common project. The projects in this initiative have slowly evolved from multidisciplinary teams to become functional transdisciplinary teams. This type of project work reproduces the challenges and opportunities of design work in professional product design teams without overwhelming the students with real economic pressures. They can then better concentrate on learning project work. Since 2006, over 200 engineering, 12 industrial design and 20 business students have discovered new ways of looking at products with the help of their teammates. Industrial mentors and students alike report that this project experience completely transformed their initial view of the product to be designed but even more that the transdisciplinary interaction has transformed their view of product design methods and efficient teamwork. From these positive experiences and the observation of missing elements in the student curriculum to improve project work, a framework is proposed to grow this initiative to another level.

In our proposed framework, three schools representing the major functions in product design activities are involved: École Polytechnique de Montréal (engineering), HEC Montréal (business school) and University of Montréal (industrial design) as shown in Figure 3. The CDIO standards and syllabus provide a solid backbone for this framework. Disciplines outside engineering involved in the framework will apply the CDIO concepts to this project. This may be a first and possibly an interesting development for the CDIO initiative. The extension of the CDIO standards and syllabus from engineering to other product design related disciplines will at first serve to develop integrated curriculum and assessment tools.

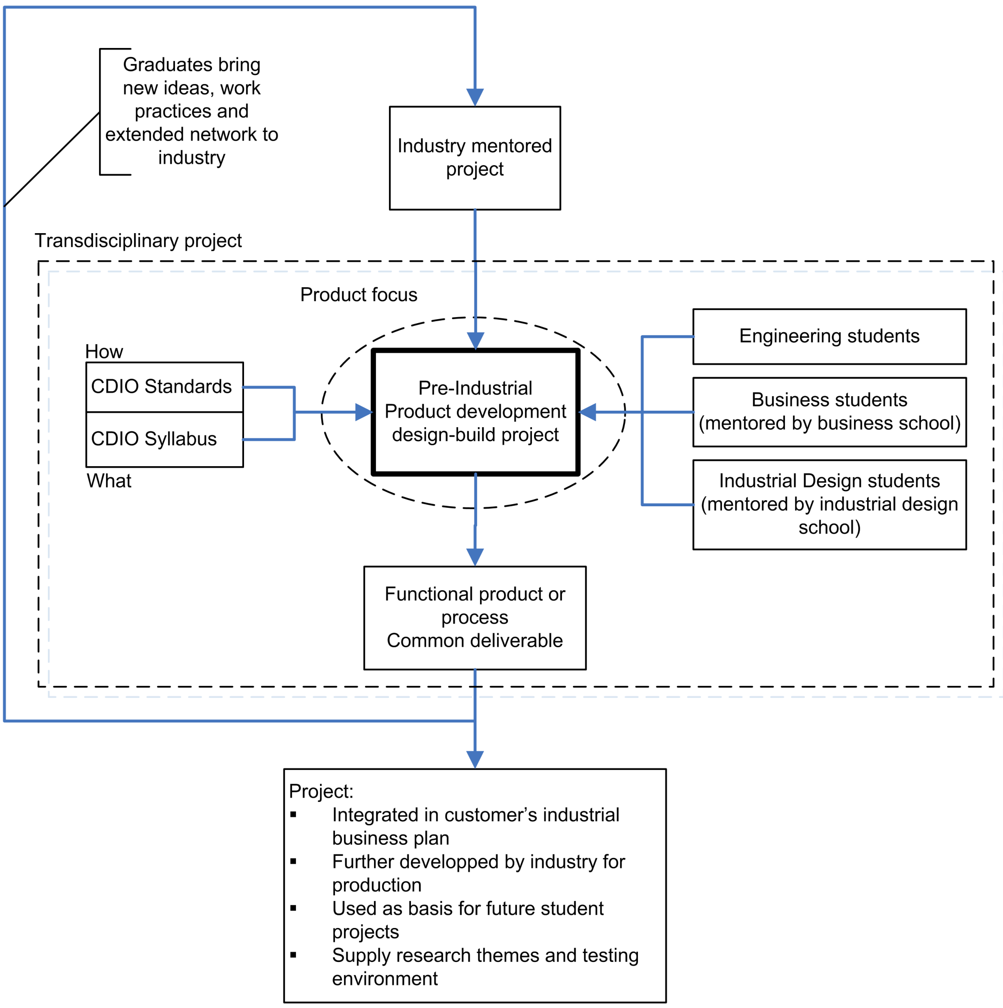

Figure 3. Proposed Framework

The framework proposes activities surrounding a central industry mentored development project for graduate and undergraduate studies. Design activities across multiple disciplines align more easily when a common goal with common deliverables is identified from the start. A common goal does not mean a clear goal however. Projects are selected to be open ended design problems with no clear and evident solution. It is in this type of problems that a transdisciplinary team truly shines. The product centric view of transdisciplinary student capstone projects generates real advantages for all stakeholders as shown in Table 2. The proposed framework will structure and develop these observed advantages in existing projects to generate a wider industry base for mentoring future projects.

Table 2
Advantages of proposed framework

<table>
<tr><th colspan="2">Project wide</th></tr>
<tr><td colspan="2">Innovative solutions to complex problems from transdisciplinary decision making.</td></tr>
<tr><th>Sector</th><th>Disciplinary</th></tr>
<tr><td>Industry
▪ Direct university contact with project mentoring.
▪ Technology transfer of developed projects.
▪ Access to the results of 6000-8000 hours of development team efforts.</td><td>Engineering
▪ Confront complex open ended problems with multiple solutions and social components.
▪ Answer “Why develop this product” essential in sustainability issues.</td></tr>
<tr><td>Research
▪ Industry needs based research
▪ Technology development and licensing.
▪ Access to in-context teams for concept testing of development processes or project tools.</td><td>Industrial design
▪ Learn to interact with technical issues early on and throughout the project
▪ Learn to interact with business issues early on and throughout the project
▪ Introduce and defend the user-centric approach in the project</td></tr>
<tr><td>Training
▪ Train students better prepared for project work.
▪ Modify training curriculum through in-situ project observation.
▪ Develop better university-industry networks.</td><td>Business
▪ Work from start to finish of the project with a technical development team.
▪ Follow through all project steps up to manufacturing of prototypes and possible market introduction.</td></tr>
<tr><th colspan="2">In the Future</th></tr>
<tr><td colspan="2">Students are to experience multinational project collaboration.</td></tr>
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Through this in context experience of project work dedicated to deliver a single integrated product, the knowledge barriers and conflicts between disciplines appear quickly. The process used to solve complex problems, conflicting issues and build consensus in the project team break the disciplinary boundaries and with time can achieve true transdisciplinary project work. Once true collaboration is achieved, successful seamless product design experiences can emerge.

To date, one of the most interesting outcomes of these transdisciplinary projects is to have one of the student vehicle projects brought to market. The student generated market, technical, product design and financial analysis permitted the start-up company to view its product in a new light, redefine it and convince investors to finance professional industrial R&D. The commercial product will be presented publicly in June 2011, one year after the end of the student project.

THE FRAMEWORK AND ACADEMIC RESEARCH

The student projects also generate academic research subjects. The close proximity of this framework's transdisciplinary projects and the industrial practice of product design creates opportunities to observe, test and develop new product design practices. The involvement of MATI Montréal in educational research and technology supported education tools make it uniquely positioned to support this framework. Existing multidisciplinary research efforts in distance collaboration tools, e-learning and educational portfolio can be applied in a project context as multinational project collaboration tools, electronic support for team information archiving and knowledge management.

The immersive sketching and model making electronic tools developed by the MATI's Hybridlab is a great example of the possibilities. This installation facilitates collaboration between multinational design groups by providing a single virtual ideation space that can be shared to collaboratively generate full scale sketches in an immersive space. The installation presently connects 5 universities in Canada, Germany, Switzerland and the USA. Other supported research subjects and activities include:

- Learn how to improve collaborative work environments and team dynamics.
- Develop new tools to support collaborative project work (local or remote).
- Study creativity and innovation in project teams (fully equipped observation room).
- Work on sustainable development decision tools for project work.
- Propose school curriculum modifications based on student's difficulties observed in a project context.
- Transfer acquired knowledge on teamwork and collaboration tools to industry.
- Supply research services to industry to test new project management methodologies.
- Use international academic contacts to create multinational student project teams.

IMPLEMENTING PROPOSED FRAMEWORK

Formalizing and expanding the undergraduate transdisciplinary projects across École Polytechnique is the first step to continue building relations with industry. New sectors selected for transdisciplinary project proposals include aeronautics, electronics and software, building infrastructure and medical devices.

In parallel, MATI Montréal will support a transdisciplinary advisory team, 3 representatives from each school involved in the framework, to build a new graduate program. The advisory team will:

- Meet with local and international innovators in product development (Cirque du Soleil, Bombardier, RIM, Pratt&Whitney, Sid Lee, Cascades, Virgin, Google, Apple, etc...)
- Combine and build internal knowledge on innovation (engineering, marketing, philosophy, history) to integrate in program proposal.

- Prepare small group discussion sessions with industry to build and assess program proposals in a continuous improvement approach.
- Test and use the collaborative tools and environment that will be later proposed to students.

From this research and field studies the advisory team will propose a microstudy program (15 credits) planned for September 2012. It could expand to a study program (30 credits) and finally a 45 credit masters program planned for 2014.

CONCLUSION

Based on observations made in industry and during transdisciplinary student projects since 2006, the need to further prepare students for complex project work was felt. To achieve this, a framework linking 3 schools involved in product and process design activities is proposed. This framework defines the project environment where students from École Polytechnique de Montréal (engineering), University of Montreal (industrial design) and HEC Montréal (business) will collaborate. A multidisciplinary research group, MATI Montréal already involved with all partners, will be the central hub to build this framework to a master's program by 2014.

The proposed framework defines a project environment where students develop product and processes for industry using an open ended mandate. Solutions to be developed must both extend the students acquired knowledge and abilities but also challenge the industrial mentor's view of its proposed project. The transdisciplinary structure of the student teams permits this broad view of design problems by combining knowledge from different fields into a single project outcome.

The involvement of MATI Montréal for academic research in project work environments including team dynamics and collaboration tools provides opportunities to further improve student training and develop innovative design methodology for industry. International academic and industrial partners are welcomed to build this framework so multinational transdisciplinary student projects can become a reality.

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Biographical Information

Daniel Spooner is associate professor at École Polytechnique de Montréal. He also teaches at Université de Montréal's School of Industrial Design. In the last 18 years, he has lead development teams for more than 70 products in the transport, consumer, medical, and telecommunication industries. He operates his own product design and engineering consulting firm involved in complex system design. He contributes actively to the CDIO capstone project initiative at École Polytechnique since 2006.

Jacques Raynauld is full professor at HEC Montréal where he holds the Chair on Teaching and Learning in Management Education. He is also the director of MATI Montréal and leads a large research/transfer initiative on integrated curriculum design, accreditation processes and learning assessment portfolio tools.

After almost twenty years as a practising industrial designer, providing services to clients in most of Québec's industrial sectors, Philippe Lalande is now a professor and researcher at the School of Industrial Design of the Université de Montréal. Exploring ways of including digital technologies within the academic program of the School, his research also spans various subjects related to the application of 3D modelling techniques to the design process, in particular Rapid Prototyping. He is the director of Formlab, a research facility dedicated to the development of physical and virtual modelling techniques and teaches courses related to this area of specialization as well as the Professional Practice of Design. Since June 2009, Philippe Lalande is Chair of the School of Industrial Design.

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