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Introduction

To what extent can thirty years of cognitive and emotional friction in education - as teacher, system developer, educational designer, manager and researcher - be formulated in terms of arguments in such a way that they would exceed the level of idiosyncratic and haphazard observations, and that they could be used as premises in some kind of scientific reasoning? The present study is based on a long series of projects which have gradually led to the formulation of working hypotheses on how to design solutions for learning and teaching more effectively. These solutions ranged from courseware applications and tools to entire learning environments (in the non-technological meaning of the term).

These projects were real-world projects. They were mostly commissioned by some kind of instance such as a publisher, a company, a university, an institution, or a government body. Some projects were submitted by us (such as European projects), but
even then it was mostly on behalf of such an instance who wanted to solve a specific problem on the level of company-specific vocabulary, pronunciation training for immigrants, or communication skills with clients. The acceptance of the project entailed a heavy responsibility not only in terms of the money invested, but also toward the commissioner, the users (learners and teachers) and to our own staff.

In order to find a solution for a specific problem, very little knowledge was available at the time. Except from some ill-grounded checklists, no methodological frameworks were available in order for us to simply apply them. For every project, a specific strategy had to be designed. The responsibility was always huge, so we learned to be very careful with formulating working hypotheses based on theory and practice, specifying in detail all uncertain factors. We gradually succeeded in providing methodological frameworks for most project phases, except for the creative part of the design process which will probably – and hopefully – always remain creative and intuitive to some extent.

We spent more and more time in trying to achieve better results, trying to reduce project cost at the same time. We integrated what we thought we learned in previous projects in the design of the new project. So we gradually spent more time and attention on design, defined as pre-development, which led to Colpaert 2004. Since then we have been conducting more and more research on how to design, formulating hypotheses along the way. Hypotheses which focus on how to solve concrete problems such as:

- How can we work in a more methodological, systematic and justifiable way? How can we integrate learnings from the past, both theoretical and practical, into new concepts?
- How do we design solutions which yield a measurable learning effect? How can we prevent that unexpected factors jeopardize the effect of our design?
- Why is it so difficult to observe a significant difference when trying to measure the effect of technology?
- Why is it so difficult to know what learners and teachers really want? Do they actually know what they want?
- How can teachers, instructional designers, researchers and software engineers communicate and understand each other better?
- How can learning content embody more didactic functionality and becomes less expensive to develop at the same time?
- How can we convince teachers to invest more in student-centred education?

Few publications have been written about our projects for two reasons, as explained in Colpaert 2010. First, there was little time to write project reports; all of the available time went to working out a solution in real-world, with all responsibilities involved. Secondly, it was difficult to describe what we had learned within one project in terms of findings for others to build upon.

Now our design methodology has grown into something very specific and operational, now it has gone through some empirical validation in our own courses and projects, now it has been presented and applied worldwide, now we even have given it a name, we are ready for substantial peer feedback on a more scholarly level. And this feedback is needed as the proposed model does not fit within the current canonical list of accepted research methods in education (such as Cohen et al., 2011), which is the main reason why we decided to publish it now.

Is there a field of Educational Engineering?

When W.W. Charters found it timely to ask this question in 1945, he was –obviously– not referring to a possible role for technology in education, but to a clear need for an engineering approach based on the definition given in 1941 by Hoover & Fish:

”Engineering is the professional and systematic application of science to the efficient utilization of natural resources to produce wealth.” (Charters 1945, 31). Charters carefully details how he understands the terms professional, systematic, application of science, efficient utilization, natural resources and wealth from an educational
engineering point of view. His educational engineering method comprises five steps (Charters 1945, Charters 1951):

- the acceptance of an idea to develop, a problem to solve, or a question to answer;
- the logical definition of the problem;
- the analysis of the problem in order to discover the factors that must be considered;
- project construction and execution;
- evaluation

Educational engineering, still according to Charters, is a profession. The educational engineer is not a teacher nor a scientist, but the link between teacher and scientist. He/she is also builder. As a builder, (s)he has to apply theory onto practice, assuming at the same time a significant responsibility towards the public. More importantly, it is an attitude. Engineers have a passion for efficiency: they lie awake worrying about a problem to solve, a question to answer. Last but not least, Charters mentions the problem of evaluation: how do we measure the efficiency and effectiveness of what we have created? Educational engineering can also play a role in behavioural science: “If I am not mistaken, historians of science believe that until recently engineering made more contributions to physical science than physical science did to engineering. Educational engineering may have similar contributions to make to behavioural science.” (Anderson 1961, 381)

But what is engineering exactly? The term itself often collocates with other familiar terms such as medical, musical, linguistic, aerospace, software, genetic, mechanical, architectural and chemical. The traditional definition, such as the one given on Wikipedia (“the discipline, skill, and profession of acquiring and applying scientific, economic, social, and practical knowledge, in order to design and build structures, machines, devices, systems, materials and processes”), does not help us any further. Billy Vaughn Koen on the contrary focuses more on the engineering method defined as: “the strategy for causing the best change in a poorly understood situation within the
available resources.” (Koen 2003). Engineering is a strategy to be used for devising the best possible real-world solution as a working hypothesis based on theory and practice, when not enough knowledge is available, taking into account the specificity, limitations and affordances of the context. Engineers build the best possible planes, but they are unable to prove that they will never crash. They build the best possible bridges, but they are unable to prove that they will never collapse. So should educational engineers try to build the best possible educational artefacts and environments, knowing that these might fail or underperform under some specific combination of unexpected circumstances.

This is why engineers are not only interested in the discrete qualities of their finished product, but in order to improve it – or in order to avoid possible failures to an absolute minimum – they will focus on improving the engineering process itself, more specifically by validating and readjusting the working hypotheses that served as tenets for their design concept.

This engineering approach fitted well within the very nature of our R&D activities described above. We now state that Educational Engineering is an Instructional Design model for guiding the design, development, implementation and evaluation of educational artefacts for learning, testing and teaching. These educational artefacts can be documents, tools, content, concepts, models and solutions such as textbooks, syllabi, lesson plans, curricula, graded readers, exercises, tests, applications or electronic learning platforms.

The term engineering does not necessarily refer to technology, but it primarily denotes the typical actions we have to undertake when not enough knowledge is available for attaining our goal. Engineering is not only about solving practical problems by applying scientific knowledge, it is also about building knowledge through
real-world implementations, in a systematic and verifiable way, using working hypotheses that should be empirically and theoretically validated.

Educational engineering is needed because there is not enough knowledge available for creating perfect artefacts. By its very nature, education can and will never be perfect. It will always be l’art du possible. Educational Engineering is geared towards obtaining the best possible results, applying the best possible methodologies, taking into account as many actors and factors as possible.

**Educational Engineering as Instructional Design model**

So if Educational Engineering can be considered an Instructional Design model, how does it fit within past and current approaches? Since Charters and Anderson, Instructional Design models have undergone a significant evolution and they have fanned out into wide variety of denominations: instructional, educational or pedagogical design or engineering models. The term engineering is being used less frequently, except in French or Spanish literature, where ingénierie pédagogique and ingeniería pedagógica or ingeniería didáctica are quite common, although mostly referring to a strong link with technology.

It is not our intention to list here a complete overview of all instructional design models. We therefore refer to frequently cited sources such as Ryder 1995, Richey 2011, Reigeluth 1983, Gustafson & Branch 1997 and others. A perhaps more pragmatical approach, partly suggested by my students, is the following typology. We make the distinction between design-process oriented models, product-feature oriented models and teaching-learning process oriented models.

*Design-process oriented models* such as the Critical Events Model (Nadler 1982), the CASCADE model (Nieveen 1997), the Systems Approach (Dick and Carey
1996) and Rapid Instructional Design (Thiagarajan 1999), focus on the ‘making of’
educational artefacts, from course materials to entire learning environments. *Product-
feature oriented models* such as Cognitive Multimedia theory (Mayer 2001), the Four-
level Evaluation Model (Kirkpatrick 1994), the ARCS model (Keller 1983) and the
Cone of Experience (Dale 1969) focus on the requirements educational artefacts should
meet in order to comply with psychological (motivational), technological and
pragmatical findings. Also theories such as Self Determination Theory (Deci & Ryan
2002) and the L2 SELF model (Dörnyei & Ushioda 2009) focus on product features to
some extent as they clearly present findings which should be taken into account,
especially on the level of motivation. *Teaching-learning process oriented models* such
as the Nine Events of Instruction (Gagné 1985), Elaboration Theory (Reigeluth 1992),
Experiential Learning (Kolb 1984), Component Display theory (Merrill 1983) and
4C/ID (Van Merriënboer 1997) can also be considered product-feature oriented models,
but they focus more on the specific process of learning and instruction designers should
chose in function of a specific context.

Educational Engineering can be considered a design-process oriented model.
Generally speaking it distinguishes itself from other design-process oriented approaches
on several points. First, Educational Engineering focuses on a larger process than on
design alone. It also embraces and clearly specifies other stages such as Analysis,
Development, Implementation and Evaluation (ADDIE). The Analysis stage focuses on
the identification of elements of the learning context which are amenable to
improvement, or which should be taken into account during design, but does not state
anything about the eventual design. Design focuses on the conceptualization,
specification and possible prototyping of educational artefacts. Result of the design
stage is a mental representation, a virtual construct, a blueprint or even a metaphor.
Actual development is clearly left for its proper stage, followed by Implementation and Evaluation. Educational Engineering states that more time, energy and effort should be put in Analysis and Design as these stages are crucial for the eventual quality and effect of the targeted product.

Educational Engineering is based on real-world iteration: its starting point is a concrete problem, but it does not focus on the problem alone. It focuses on how to reach an optimal solution which in most cases cannot be realized in one step, due to resistance, financial limitations, technological challenges or practical constraints. The long-term engineering process goes through a series of ADDIE lifecycles (fig.1), and each of these cycles formulates a very precise and justifiable intermediate change on the pathway to the optimal solution. The evaluation stage of every cycle not only validates the suggested changes, but also confirms or readjusts the concept of the optimal solution along the way. This concept serves as a lighthouse for all actors involved. The lighthouse metaphor is not accidental here: a lighthouse shows direction to boats, but it never is their final destination. So will the eventual solution be different than the initially conceived optimal solution.

Contrary to Rapid Application Design (RAD) or Rapid Instructional Design (RID), Educational Engineering does not insist on much iteration during design itself, as it considers its typical real-world iteration as the most important source of information. While RAD and RID consider real-world iteration too slow and time-consuming – which in a large number of cases can be a valid argument – the goal of Educational Engineering is more than creating optimal solutions: it also intends to validate research hypotheses, build knowledge and share expertise in an academic context.
The optimal solution is a hypothesis, but so are the consecutive intermediate loops. Every hypothesis is based on theoretical findings, practical experience, and the outcome of previous loops. The role of theory is to feed the process with as many useful, relevant and substantiated findings and concepts as possible, in order to increase the efficiency of the process, to guarantee the effectiveness of its product and to reduce the risk of failures. In the case of language learning and teaching for example, theories to be taken into account pertain roughly speaking to the following fields: pedagogy, psychology, technology, linguistics and specific sub-disciplines such as Human-Computer Interaction (HCI), Second Language Acquisition (SLA), Computer Mediated Communication (CMC), Motivation Theory, Activity Theory and Cognitive Multimedia Theory. The integration of this theory typically happens during two stages. During the Analysis phase, the educational engineer checks whether or not enough theoretical knowledge and findings are available for carrying out the project, and (s)he has to make the inventory of all required knowledge for designing the optimal solution. Secondly, during Design, the final shape will to a great extent, but not exclusively, be determined by theory. So theory is not directly applied to nor translated into the solution (like applying 4C/ID as such in a concrete learning situation), but it serves as one of the premises of a logical reasoning that forms the hypothesis.

While ADDIE is a systematic model, meaning that the output of the previous stage serves as input for the next one, and often criticized for being too rigid, it should not necessarily be seen as a waterfall model. Backtracking to previous stages is
certainly possible with Educational Engineering. Iterative thinking is being considered useful and even advised, although the real iteration is to be found in the consecutive real-world loops. Educational Engineering focuses on building knowledge about the process, in a research-based and research-oriented way, and therefore it needs to be able to justify every decision along the way, albeit in terms of Bayesian epistemology (Hartmann and Sprenger 2010). This is why we need more detailed conceptual (what to do ?) and methodological (how to ?) frameworks for every stage.

Educational Engineering intends to be a universally applicable model (statement to be validated), but it does not state anything about the eventual shape of the solution (as this mainly depends on the context), nor about which theories are relevant, useful and/or applicable. The product should not be evaluated as such on its features, and this for two reasons: a/ a product is by definition always an intermediate solution and b/ as the product will always depend on the local context. Applying the same model leads to polymorphous results. Design should not be confused with shape. While we can easily observe shape, good design often remains invisible. Because design refers to the work behind the shape.

**Distributed Design: the concept**

This optimal solution, the virtual product of the design process, will always be a hypothesis, but the proposed process itself will also remain a hypothesis to be continuously subject to theoretical and empirical validation. We will now describe how six hypotheses, grown out of the confrontation of practical experience with theoretical findings, have led to our own specific design model.

- *The Ecological Paradigm Shift:*
Research into the learning effect created by a single educational artefact, such as a new technology (tablet, serious game, IWB …) often leads to the No Significant Difference Syndrome (the more difficult to prove the effect, the more complex the statistics), or at least to non-generalizable results. The main tenet of Distributed Design is that the added value of a particular educational artefact is proportional to the extent to which it contributes to the creation of an optimal learning environment (OLE).

The term learning environment in its traditional acceptance refers to a collection of components such as actors (learner, teacher, parent, policy maker, content provider …), content, infrastructure, technology and models (for teaching, learning and evaluation). The Distributed Design approach defines the learning environment more as a self-regulating system, a learning ecology, where more attention goes to the interplay between the components of the environment, the context and the rationale behind its design. It focuses on the possible effect on learning of this entire ecology, and tries to research to what extent this ecology can be optimized, in other words leading to better results for all actors involved, both in quantitative and qualitative terms.

An OLE is a blueprint of an ideal learning environment which by definition will (perhaps) never exist. As already stated, its function is that of a lighthouse: it shows direction. In the same vain, an OLE should perhaps never be realized as such, but its main purpose will be to guide the decision process along the way. An OLE also has its specific scope. This scope is determined by the users of our educational artefacts: it can be a class, a grade or degree, an institution, a country or even the entire world (e.g. Open University).

An OLE cannot be realized in one step, but it should inspire small changes to be undertaken in the existing learning environment, typically every year. Every redesigned learning environment should always be seen as an instantiation of the OLE. This
an instantiated learning environment or ILE should be specified in detail. The purpose of an ILE is to test a hypothesis, and after evaluation and validation, formulate a new hypothesis leading to a new ILE along the pathway to the OLE. The number of changes in the design of a new ILE, compared to the previous one, depends on available resources, on resistance to be expected, on the research-oriented nature of the activity etc. Hypotheses are based on previous experience (evaluation of previous ILEs, exchanges with colleagues worldwide …) and on theory. The reasoning leading to a new hypothesis should be based on a sound construct based on substantiated evidence. It is obvious in this respect that also the design of the OLE can and should be adjusted along the way on the basis of these intermittent evaluations.

- **Psychological Paradigm Shift**

An OLE should be designed with a clear focus on a particular pedagogical goal. Pedagogical goals are mostly well documented, easy to find, explicit and detailed. Their formulation largely depends on the scope of the OLE, and they range from lesson plans over course goals (“At the end of this course you will be able to …”) and grade descriptors (French 101 or Common European Framework for Languages), to country level (official learning programmes). The term optimal learning environment refers to its very *reason d’être*, i.e. to offer the best possible guarantee that the set pedagogical goals can be realized as efficiently and effectively as possible.

However, especially in cases of lesser motivation, it is counterproductive to focus exclusively or too directly on the realization of these pedagogical goals. It is far more efficient to focus on personal goals first. Personal goals can be considered subconscious volitions that hinder or stimulate the learning process. The problem is that these goals are quite difficult to elicit (Colpaert 2010).
The starting point – or angle of attack – of Distributed Design is the point where personal goals and pedagogical goals conflict such as in cases where students have to learn French but may not be motivated to do so, where students have to learn to be autonomous but they may prefer strong guidance, or where students should learn how to cope with chaos but they may prefer a strong structure.

Most of the effort in Distributed Design goes into trying to reconcile these conflicting goals into a strong concept. The concept underlying an eventual OLE can be expressed as a metaphor (such as a city, a space station, a forest or a power plant). This concise representation makes sure that all actors involved (designers, developers, users and stakeholders) carry more or less the same mental image. This is important for the design team, but also for the teachers and learners.

- Distributed Design Hypothesis:
The term Distributed originated from Computer Science (Distributed Computing or Programming). A distributed system consists of several autonomous computers that interact with each other through a network with a view to achieve a common goal. The term Distributed Learning is being used for several types of Distance Learning (Lea and Nicoll 2002). Distributed Design in our case is defined as: instead of focusing on one aspect in design, it is always better to make a deliberate choice out of a wide variety of options, and to spread the design effort over several axes such as content types, learning and teaching activities, evaluation types, media and technologies, locations and actors. In fact, our first two hypotheses are a form of distributed approach: the first one as spreading of our focus over the entire learning environment, and the second one spreading our focus over pedagogical and personal goals. The more we spread, at least
in our minds, the more efficient the design process and the more effective the learning environment.

- **Ontological Specification:**

  While the first stage in Design is conceptualization, the second one is specification. Specification typically consists of a long document, especially in the case of software engineering. Detailed documents, however, do not prevent misunderstandings. Also between pedagogues and practitioners: this is exactly where Charters saw the primordial role for the educational engineer.

  An ontology can be defined as an explicit specification of a conceptualization. Ontologies are extremely useful, especially in the case of knowledge sharing and reuse (Gruber 1995). Instead of a long and detailed specification, Distributed Design focuses on a strong concept that can easily be understood by all people involved, and that can inspire them. Four stages can be distinguished during specification: pedagogical specification (teaching model, learning model and evaluation model), architectural specification (interactions among actors and content, both inside and outside the classroom, needed for the specified pedagogical model), content specification (accurate description of commercially available content, Open Educational resources and/or self-made content), and technological specification (existing technologies, technologies to be adapted, technologies to be developed). Each of these specification models can be shared as ontologies, once they have been validated as hypotheses.

  The best way to bridge the gap between educationalists and technologists is to teach educationalists how they can specify what they need in detail: what can be specified, can be developed.
**Generic Content Structuring:**

A generic in-depth structure is needed for making content more sustainable, reusable, exchangeable, (trans)portable, exploitable, authorable and open, for two reasons. The first one is that development of learning content is too labour-intensive, the second one being that a completely new series of related products and services is emerging, made possible through recent evolutions in the field of technology (smartphones, tablets, virtual worlds, ambient intelligence …), pedagogy (constructivism, serious gaming, collaborative writing, dynamic systems …), educational practice (Open Educational Resources, changing role of parents, social networks …) and research (motivation theory, instructional design, adaptive testing and intelligent tutoring).

This generic in-depth structure should form the basis of an author’s database, from where derived products and services can be generated such as traditional textbooks, tailor-made textbooks, delivery of content for specific purposes (Powerpoint, Interactive Whiteboard, …), Open Educational Resources and interactive applications.

**Teacher Support Hypothesis:**

Competence-oriented and student-centred education, the ultimate goal of any instructional design effort, will eventually fail if teachers are not fully supported.

Therefore, a Performance Support System should be designed both for teachers and students, with accurate specification of the institution’s support for each learning/teaching activity. Examples include online meeting and teaching tools (such as Adobe Connect, FlashMeeting, Elluminate), wikis, planning and reporting tools etc.

**Educational Engineering as Research Method**
Educational Engineering is a professional activity based on a passionate attitude toward real-world education. In this section, we will try to explain why and under which conditions it can also be considered a research method. We can distinguish four levels of measurement: effect on learning, product features, process indicators, and hypothesis validation.

- **Effect on learning**
  
  The eventual goal of any educational research is to improve education, in many cases by focusing on the effect of educational artefacts on learning. While the eventual goal of Educational Engineering is to increase this effect on learning, it does not focus explicitly on measuring this effect. Educational Engineering focuses more on the preliminary conditions for an effect to occur, leaving the actual measurement to other (existing and proven) methods.

- **Product features**
  
  During the Analysis phase, as mentioned above, the Educational Engineer has identified aspects amenable to improvement in the learning environment. These aspects can be related to learner motivation, teacher support, availability of content, the evaluation model or technology. During one specific cycle, (s)he can focus on one such an aspect, but the typical activity of the educational engineer will also be to juggle with all other requirements for the educational artefact as ‘product’. These requirements can be specific to a local context, but they should also be based on more general findings, concepts, models and theories such as Cognitive Multimedia Theory, the Technology Acceptance Model or Self-Determination Theory.

Examples of product features include qualitative aspects such as teacher fit, learner fit, acceptability (perceived usefulness), locus of control, user-friendliness, adaptive intelligence, interactivity, usefulness and meaningfulness of tasks or didactic
quality of content, and quantitative aspects such as price, life cycle, initial usage, content size and richness, possibilities for tracking and logging, and installation requirements. 

There is a clear need for a ‘juggling’ framework or model which should enable designers to take into account all these requirements at the same time. One of its principles should be that it is better to comply with as many requirements as possible than to excel on one specific aspect.

- Process indicators

More importantly, engineering as research method focuses on the engineering process itself. How can it be made more efficient and effective? This process of engineering the process itself is called re-engineering. Let’s first define a process as a series of activities. Reengineering is about determining the series of activities to be undertaken, their weight, order, duration, intensity, and the way they are carried out. Changing one of these elements entails the need to observe the consequences of this change on product level (see previous point), but more importantly on the process itself.

Process indicators include: development time, general cost, team cooperation, number of practical problems encountered, strength of the design concept, accuracy of the specification, and resistance encountered during initial implementation.

- Hypothesis validation

As already mentioned, engineering starts with building a working hypothesis that should be validated. Hypothesis validation implies the calculation of the delta between actual outcome and expected outcome. These outcomes can be specified both in terms of product features and of process indicators, but, if we want to focus on epistemological contribution, hypotheses should be formulated in such a way that
the actual outcome can be compared with the expected outcome in an objective, measurable way. This means that for our own hypotheses described above we should add the expected outcome on product and/or process level, and that we should reformulate them accordingly.

However, in most cases it will be impossible to validate such a hypothesis in one cycle. Measurement at every cycle will only modify the hypothesis probability to some extent, what we could call a Bayesian epistemological approach (Hartmann and Sprenger 2010).

Educational Engineering as Research Method can thus be defined as a specific strategy to build knowledge about the engineering process itself: when designing, developing and implementing educational artefacts, what can we learn about the most efficient and effective way for doing so? Educational engineers can build knowledge through the formulation of process hypotheses based on theory and previous experience, and through their validation in terms of measuring the difference between actual outcome and expected outcome, observable on the levels of product features and/or process indicators. Validation can only be carried out in real-world contexts, when not enough knowledge is available for solving a specific problem. In a subsequent publication, we will discuss this aspect of measurement in detail, and show how we have been reformulating our hypotheses along the way. We will also focus on a possible framework for product features (‘juggling act’) and process indicators (‘re-engineering’).

Now to what extent is Educational Engineering different from other research methods mentioned in the canonical Cohen et al. 2011? It encompasses several aspects which are not covered by other methods:

- Educational Engineering is real-world: it starts from a problem to be solved, a situation to be improved in the real world.
Educational Engineering allows practitioners to transform their daily work into research: it is not a method they can pick from the shelf and apply on-the-fly in real-world situations; it requires practitioners to become instructional designers – educational engineers – first; the research becomes something they no longer have to do on top of their daily activities (the Sunday Evening Syndrome), but they can easily turn one or more of these activities (by definition always amenable to improvement) into research.

Educational Engineering is process-oriented: it is the typical activity of readjusting design processes based on hypothesis validations, while monitoring the required product features at the same time; it focuses on improving the process as a better way to improve the product in the long run, on formulating generalizable engineering principles, and on building and sharing this knowledge.

Educational Engineering is based on hypothesis validation, whereby we do need advanced statistics in order to show decreasing differences between actual outcomes and expected outcomes;

Educational Engineering encompasses more than design alone: it also focuses on Analysis, Development, Implementation and Evaluation stages of the Engineering cycle.

Practice-based approaches such as Real-World Research (Robson 2011), Action Research, SOTL (Scholarship of Teaching and Learning), Practitioner-Led Research, Teaching as Design Science (Laurillard 2012) and Reflective Exploratory Practice encourage teachers to participate in research, but they differ on more than one aspect mentioned in the list above, and do not present specific research activities that would be different from the ones mentioned in Cohen et al. 2011. Three other approaches deserve our special attention in this respect:

- *Retrodictive Qualitative Modelling (RQM)*, which offers “a systematic method of describing how the salient components within a dynamic system interact with each other to create unique development paths – or ‘signature dynamics’ – that lead to system-specific outcomes as opposed to other possible outcomes.” (Dörnyei 2011, 11). Instead of trying to predict, RQM focuses on understanding from a complex dynamic systems perspective why certain components of the system ended up with one outcome option and not with another.

- *Design-Based Research (DBR)*, which focuses on quasi-experiments to estimate the causal impact of interventions on a target population in their natural setting in order to test the ecological validity of some theory and to generate new frameworks for conceptualizing learning and instruction. This type of research typically takes place
through continuous cycles of design, enactment, analysis and redesign (Design-Based Research Collective 2003, Brown 1992, Wang & Hannafin 2005). Surprisingly enough, DBR does not seem to focus on the process itself, but on the effect of some intervention which is mainly based on a pedagogical or technological theory or model.

- Educational Design Research (EDR), which can be considered fully design-process oriented (Plomp & Nieveen 2008; van den Akker et al. 2006). Nieveen et al. 2006 even – occasionally – mention ‘educational engineering’ explicitly when stating that we may be able to learn from “sister fields” such as engineering, which requires varied types of investigations at different stages.

Further analyses will have to point out to what extent Educational Engineering is compatible with, complementary to or forming part of these emerging approaches.

**Considerations**

There is not enough evidence to suggest that technology, or any other type of educational artefact, carries an inherent, measurable and generalizable effect on learning. There are so many context-related actors and factors involved that replication research in many other situations is needed in order to corroborate whatever finding. Researchers see themselves confronted very often with the ‘No Significant Difference Syndrome’ in this respect. The expected effect on learning has to come from a well-designed learning environment. The role and added value of technology – or any other educational artefact – is to contribute to the effect of the entire learning environment. The eventual optimal form and shape of educational artefacts thus depend on the learning environment as ecology and are by definition different from situation to situation. The best way to evaluate these artefacts is not to analyse their features in a discrete way, but to analyse the reasoning and the method applied to design the entire learning environment. The best way to evaluate a learning environment is to redesign it: in other words, the evaluator should compare his/her mental representation of an optimal (well-designed) learning environment for a specific situation with the actual
existing learning environment. In this respect, the best possible design is not necessarily
the sum of features that possess the highest possible effect on learning.

Previous projects have pointed out that even apparently well-designed learning
environment can sometimes still lead to disappointing results, and this for several
possible reasons:

- a small but relevant detail neglected during the Analysis phase can jeopardize the
targeted effect on learning;
- extraneous factors (which are impossible to detect during the design phase) can still
have an unexpected side-effect;
- available resources (financial, human, technological …) are usually being
overestimated;
- resistance (surprisingly enough mostly with people in charge, less in the mind of
learner and teachers);
- the fact that people have little insight in the factors that hinder or stimulate them
(Colpaert 2010);
- exaggerated expectations towards technology.

Reasons enough to continue with the empirical and theoretical validation of Educational
Engineering, but there is also another challenge for Educational Engineering as
research activity: the current academic evaluation system, which requires fast output in
quantitative terms (Colpaert 2012). This is a problem for Educational Engineering as it
advocates a slow approach for two reasons. The first one is that the typical engineering
lifecycle model does not lead to substantiated proof in one cycle, but it only adjusts
hypothesis probabilities over several cycles. The second reason is the multidisciplinarity
of the work, which requires inter- and even transdisciplinary approaches, which by
definition take more time to carry out and which are more difficult to publish in highly
ranked journals.

**Conclusion**

In this report, Educational Engineering has been presented as an instructional design
model for designing optimal learning environments, as a strategy to be applied when not
enough knowledge is available in real-world settings, and as an innovating research method.

This article should be situated within our attempt to transform our epistemic intuition into explicit, transferable and substantiated findings. Much work remains to be done on the accurate description of the actual research activity in terms of gauging and measuring, on the specificity of the proposed approach versus other methods, and on its validation as hypothesis. But this work can only be done in collaboration with colleagues worldwide. This is why this article should be read as an open invitation in the first place. An invitation to contribute to the empirical and theoretical validation of the proposed model.

The approach might be problematic in terms of academic evaluation, but at the same time it we believe this slowness paradoxically enough is a way of building knowledge faster in the long run, it allows practitioners to transform their daily work into research, and it entails challenging and cutting-edge research questions such as whether or not it makes sense to conduct experimental research in poorly designed learning environments.

Our most important objective is not that researchers and practitioners would follow the proposed model religiously, but that they would adopt a more passionate engineering attitude in education. Because education will always be ‘l’art du possible’.

References


