Educational Engineering as Research Method

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Version 3.6

21 March 2012

The aim of this concise document is to provide colleagues worldwide with a basis for discussion, to invite them to give feedback, and in so doing to contribute to the ongoing empirical and theoretical validation of the proposed hypothetical model.

Definition

Educational Engineering (EE) is an Instructional Design model for guiding the design, development, implementation and evaluation of educational artifacts for learning, testing and teaching.

These educational artifacts 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 gradually validated empirically and theoretically.

Educational engineering is needed because there is not enough knowledge available for creating perfect artifacts. 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.

The ecological paradigm shift

The main tenet of EE is that the added value of a particular educational artifact is proportional to the extent to which it contributes to the creation of an optimal learning environment.

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 EE 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. EE 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.

The optimal learning environment

EE defines an optimal learning environment (OLE) as a virtual construct, which is the result of a methodological and systematic design process.

An OLE is a blueprint of an ideal learning environment which by definition will (perhaps) never exist. Its function is that of a compass or a lighthouse: it shows direction. This lighthouse metaphor is not accidental: the lighthouse shows the direction to the target (e.g. the port), but is never the target itself (e.g. a rock or cliff). 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 always has its specific *scope.* This scope is determined by the users of our educational artifacts: it can be a class, a grade or degree, an institution, a country or even the entire world (e.g. the students at Open University).

An OLE should be designed with a clear focus on a specific 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 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 in this respect 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.

The concept behind an 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.

The instantiated learning environment

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 intermediate learning environment, an instantiation of the OLE. This instantiated learning environment or ILE, contrary to the OLE, 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 that also the design of the OLE can and should be adjusted on the basis of these intermittent evaluations.

The process

EE is based on justifiable and verifiable decisions, and therefore requires an engineering model such as ADDIE (Analysis, Design, Development, Implementation and Evaluation). ADDIE is a systematic model, meaning that the output of the previous stage serves as input for the next one. EE focuses on how every stage should be carried out in order to lead to better results. This is why we need methodological (how to?) and conceptual (what to do?) frameworks for every stage.

While ADDIE is a systematic model, it should not necessarily be seen as a waterfall model. Some iterative thinking is allowed and even advised, although the real iteration is to be found in the subsequent lifecycle loops. We never rely on too much iteration given the fact that real-world implementation is the most important source of information.

EE distinguishes itself from Educational Design in literature as it clearly encompasses more than design alone. The quality of the design will largely depend on the effort put in the other stages.

EE and Theory

EE is an engineering model. It pretends to be a universally applicable model (statement to be validated), but it does not state anything about the eventual shape of the learning environment (as this mainly depends on the context), nor about which theories are relevant, useful and/or applicable. EE forces the designer to select and take into account theory in the first place, and then shows when and how to integrate it. It does explain how to find and integrate theory (implementing as many useful, relevant and substantiated findings and concepts as possible).

Theories to be taken into account pertain roughly speaking to the following fields: pedagogy, psychology, technology, and subject-matter related disciplines such as linguistics in the case of language learning. Specific sub-disciplines such as Human-Computer Interaction (HCI), Second Language Acquisition (SLA), Computer Mediated Communication (CMC), Motivation Theory, Activity Theory, Cognitive Multimedia Theory, etc. should also be taken into account.

The integration of theory typically happens during two stages. During Analysis, the educational engineer has to make the inventory of all required knowledge for designing the new learning environment. Secondly, during Design, the final shape will to a great extent be determined by theory.

Both EE and theories are necessary conditions. Neither of them is sufficient on its own. Only together they can form sufficient conditions for designing the OLE. In this respect, they are complementary.

The product

The product of the EE process is a concrete learning environment. This learning environment should not be evaluated as such on its features, and this for two reasons: a/ an ILE is by definition always an intermediate product and b/ as the product will always depend on the local context, applying the same model will lead to polymorphous results.

Design should not be confused with shape. While we can easily observe shape, good design often remains invisible. Design refers to the work behind the shape.

There is however one important psychological aspect about shape: the learning environment should not only have face value or face validity, it has to create acceptance in the user's mind. The user should immediately perceive the *affordances* of the learning environment. The more the user – subconsciously even – feels that the learning environment is going to contribute to realizing his/her goals, the more the user will accept the new environment. The more reward, the more effort.

Five hypotheses

We are currently working on five hypotheses, which can only be slowly validated, in many projects, in many countries and in various contexts.

- *Personal Goal Hypothesis*: in cases of lesser motivation it is counterproductive to focus exclusively on the realization of pedagogical goals. It is far more efficient to focus on personal goals first. Problem is that these goals are quite difficult to elicit (Colpaert 2010)
- *Distributed Learning Hypothesis*: the more we spread the learning process over various moments, locations, media, strategies, actors, exercise and evaluation types, the more efficient the engineering process becomes.
- *Ontological Specification Hypothesis*: 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.
- *Teacher Support Hypothesis*: Optimal teacher support is a prerequisite for any student-centered approach.
- *Generic Content Hypothesis*: as development of learning content is too labor-intensive, a generic in-depth structure is needed for making content more sustainable, reusable, exchangeable, (trans)portable, exploitable, authorable and open.

EE itself as a hypothetical model is still under empirical and theoretical validation. Further refinement is only possible through application of the model in the most diverse contexts worldwide.

EE as research method

Now, epistemologically speaking, how do we build knowledge? What and how can we measure with EE?

Many publications focus on the impact of some educational artifact, especially technology, on aspects such as learning effect, motivation, attitude or perceptions. They also try to show some significant difference. While this evidence is eventually needed as ultimate proof, the EE approach implies that effect measurement is only useful if the learning environment has reached a level of sufficient approximation to the OLE.

EE focuses on building knowledge about the engineering process and how to improve it, using working hypotheses. The question is: which sources of information can be used for validating these hypotheses?

In fact, there are two major groups of information sources, indicators or 'gauges': there are aspects we can observe during the processes of analysis, design, development, implementation and evaluation; and there are aspects we can observe once the learning environment is being used, and which clearly relate to the engineering process.

In-process indicators relate to aspects such as information gathering (analysis phase), content development, sustainability of technology, actor involvement, efficiency of the team, amount of theory taken into account and the design concept itself.

Post-process indicators relate to aspects such as initial mental acceptance, continued use, user satisfaction, cost for learners, cost for parents, effort for teachers, comfort for learners …

These indicators depend on the project and context, but they should have been defined in advance, as part of the working hypothesis that formed the basis for the ILE. While this systematic approach is needed for research purposes (and for avoiding any idiosyncratic approaches), EE does not discard a sound amount of serendipity, especially for monitoring unexpected side-effects.

EE should be seen as a full-fledged research method but this type of research has not been mentioned so far in any overview of research methods in education nor social sciences. EE is different from, but complementary to other approaches such as:

> *Action Research*: EE is more holistic, systematic, cyclic and completely different from an epistemological point of view. While Action Research focuses on the effect of a change, EE focuses on the why of the change, how to implement it and how to measure what we want to measure.
>
> *Educational Design*: Educational Design only focuses on the design process, and mostly only on one cycle. EE encompasses many other stages in the engineering process, and on many loops. EE easily integrates any Educational design model, as long as it can be justified in the context.
>
> *Treatment-analysis experimental research*: as already stated, the final goal of educational research is to measure and prove some significant difference (e.g. effect on learning), but this is not the focus of EE, and thus these approaches are perfectly complementary.

Discussion

EE as Instructional Design model is different from other approaches, such as technology-driven (technology Acceptance Model), feature-based (Cognitive Multimedia Theory), affordance-driven, pedagogy-based (4C/ID) or demand-driven approaches.

Secondly, EE states that no educational artifact can be designed nor evaluated in an absolute, discrete way. EE does not take as a starting point the potential effect an educational artifact, or some of its features, might have on learning, nor does EE seek to create ‘powerful’ learning environments as a sum artifacts or features that possess the highest possible effect on learning. Research into the effect on learning of a particular artifact, implemented as such in an existing learning situation, seldom leads to significant differences, nor to findings that are context-free and/or universally applicable.

Finally, the integration of ICT in any learning environment is not justified without redesigning the entire environment. The reason for using any technology in education should be the result of a thorough design process.

Challenges

Previous experiences have pointed out that even an apparently well-designed learning environment can lead to disappointing results. Reasons for this might be:

- A small but relevant detail has been neglected during the Analysis phase. These details might jeopardize the targeted learning effect.
- Extraneous factors (such as the role of mother tongue acquisition on second language learning, identity issues, political decisions), may have an unexpected indirect effect.
- Available resources may have been overestimated.
- Resistance is a common phenomenon, but resistance in the mind of the commissioners of the (re)design project themselves is fatal for any engineering project.
- Most educational research intends to obtain an accurate picture of learner needs, in the best case also teacher needs, based on explicit information obtained through surveys, interviews and focus groups. This technique does not deliver sufficient information for design, as most people have little insight in what hinders or stimulates them in their learning, teaching or working activities.
- Exaggerated expectations toward technology in the mind of learners and teachers, and hype-based approaches, are still frequent on the level of educational research and policy.

A second challenge is the multidisciplinarity of the educational design and engineering activities. Interdisciplinarity (trying to understand each other’s discipline) has appeared to be less efficient than a transdisciplinary approach, focusing on the elaboration of a common rationale, formulated in terms of a sound logical reasoning, with premises that are based on substantiated evidence.

Conclusion

Engineering traditionally refers to the application of scientific knowledge to solving practical problems. While medical, musical, linguistic and agricultural engineering – just to name a few - have become accepted disciplines, not much has happened with educational engineering since W.W. Charters coined the term in 1945.

Educational engineering as a term may xx to technology. Even with this danger in mind, we deliberately stick to the term engineering as to denote the typical action we have to undertake when not enough knowledge is available in a specific discipline. Engineering is about solving real-world problems by applying a methodological and justifiable approach, and by formulating working hypotheses based on theory and practical experience.

Many teachers at higher education level are coping with an increasing pressure to publish. What we call the 'Sunday Evening Syndrome' refers to the typical psychological phenomenon where practitioners make a distinction between 'work' and 'research'. One of the main advantages of EE (and also of Action Research) is that it allows practitioners to turn their daily work into research. A remaining challenge in this respect might be the academic valorization of this kind of activity.

EE is an instructional design model, but also a research method. It intends to be universally applicable, but it leads to polymorphous results worldwide.