Active Learning and Curriculum Design

Otto Rompelman & Erik de Graaff
Delft University of Technology
Delft, Netherlands

Abstract
The issue of active learning has gained increasing interest in engineering education. It can be shown that it is a logical consequence if the development of education is considered as the result of a well-structured design process. In this paper we review the design process based on the product life cycle of technical systems. It is discussed that this methodology can be adapted to the design of education. Key issues in design are the development of a product requirements plan, the development of alternative solutions and the final choice of the most promising solution. It appears that active learning is often an attractive alternative as will be illustrated with some examples.

Introduction
Teachers in higher education are highly qualified professionals with a scientific training. Yet, Van der Vleuten (1997) comments that in their capacity as teachers they seem to ignore scientific insights. He observes that university professors appear to prefer intuition to proven facts when it comes to their approach to teaching. Something similar applies to engineers in relation to choices in curriculum design. As the design approach can be applied to all sorts of technical problems, it makes sense to apply this method also to curriculum design. We will first review a traditional design paradigm and consequently translate this into a curriculum design methodology. It can be shown that by applying this methodology, the introduction of active learning in whatever form becomes a rather natural thing (Rompelman & de Graaff, 2006).

A design methodology of technical systems
Basic methodology for designing technical systems
It is well known that the successful design of technical systems requires a highly structured approach. Such an approach is usually referred to as a methodology. The methodology applied in this paper is the concept of design as problem solving (figure 1).

Figure 1: The paradigm of the design process: design as solving a problem

In this concept it is assumed, that the designer observes a part or an aspect of the real world. His observations lead to his image of a part of the real world. Apart from the observed world he has ideas about what he thinks the real world should be, in other words: an ideal image of the real world.
reality. Now he compares the observed world and his ideal image of the world. This comparison leads to the definition of a *problem*. Solving this problem is accomplished by creating ‘something’ (a product) such that the world will look more like his ideals. In the optimal situation the real world will equal his ideal image.

Another aspect of design is its predominant role in the life cycle of products or, more general: (technical) systems. The consecutive phases of the life cycle are shown in Figure 2. These phases are rather logical and don’t need a further discussion.

The design phase comprises all preparations before actually creating something. Figure 12 depicts, that in the design phase it is necessary to take into account all aspects related to all phases of the product to be designed (production, usage, management, maintenance, recycling/disposal). The designer has to contemplate on all these issues when designing a system. In practice, this means that he has to think about the future: he should try and formulate (a) questions like

- can it be implemented and how?
- can it be used and how?
- can we verify whether the systems does what it should do and how can we do this?
- what are the costs involved?
- what is the environmental impact?
- how long should the system be in operation (life cycle) and what do we do after its life cycle has come to an end?

All these considerations will contribute to a set of design criteria; this set is referred to as the ‘Product Requirements Plan’ (PRP), which is the result of phase B in Figure 13 (ten Haaf, Bikker & Adriaanse). In fact, the requirements imposed by the reflection on ‘the future’ lead to a set of boundary conditions in the PRP.

*The Product Requirements Plan (PRP)*

The Product Requirements Plan (PRP) plays a key role in the design process. Here the influence of aspects of all phases of the life cycle as depicted in Figure 12 becomes apparent. The PRP comprises two main issues:

1. The function of the system (what is it supposed to do)
2. The boundary conditions

These boundary conditions are a translation into operational terms of all wishes, preferences and requirements as formulated by all people involved (manufacturers, users, operators, etc). It is important to note, that this translation is the full responsibility of the designer.
The design phase elaborated

The design phase can now be elaborated as shown in Figure 3. As can be seen from the figure the subsequent phases are not unidirectionally related. This reflects the dynamics of the entire process in which it is allowed (and sometimes even advisable) that in the process we may return to a previous phase, if we discover that assumptions in a previous phase appear to be erroneous.

![Figure 3: The design phase in detail](image)

There are five essential steps in the design phase:
1. Define the problem
2. Define criteria to be met by the solution: reflection on ‘What do we want?’, rather than ‘How do we want it?’; this leads to ‘Product Requirements Plan’ (PRP) Develop different concept systems (solutions); usually, a problem has more solutions than just one!
3. Simulate concept solutions evaluate the concept systems with reference to the, leading to the Product Requirements Plan (PRP) and choose the most promising concept system.
4. Select the best solution according to criteria (see 2.)

Consequences for designing education

In this section the design framework as discussed above is adapted to curriculum design. This leads to the following characterisation of the five essential steps:

1. **Problem analysis.** It has been discussed elsewhere, that the educational problem should be defined in an output oriented way. So, it should not be defined as ‘in our program we need a course in mathematics’ but ‘in our program the students need a module after which they have acquired the following skills, knowledge, competencies: .......’. In fact, the question is: “What is this course envisaged to achieve?”
2. **Definition of requirements.** Similarly to the PRP of engineering products we can define a Course Requirements Plan (CRP). The main issue in this CRP is the educational problem as mentioned above. Consequently, criteria have to be defined, that are to be met by the solution. The following four categories can be identified:
   1) About the learning outcomes:
      - the outcomes should be realistic given the attributes of the target group (prior knowledge skills) and the time available for the students (credit points!) the outcomes should be testable; if not, they should be left out or reformulated.
   2) About the preparation and production (planning) staff time (costs!) development of course material, assessment. arrangement of laboratories, computer rooms etc.
   3) About running the module/course/programme,
      - staff time,
      - infrastructure: rooms, laboratories, equipment, communication, office hours, web-support, e-mail, ...
4) About the life cycle span of the module/course/programme use of (parts) of the module/course/programme in time discussion of prolongation, modification of the module.....

The fact that the latter issue is taken into account implies that right from the beginning it is assumed that whatever course will not last forever.

III. *Creating concept solutions.* Different educational systems may be proposed that may be suitable for solving the educational problem as previously defined. These imply lectures, laboratories, working groups, projects and/or combinations of these.

IV. *Simulation of concepts.* Simulation in its mathematical or technical sense is usually very difficult since it involves people. This means that other ways of predicting its behaviour should be employed. It can be observed in practice that many educational systems (programmes, curricula, courses) are designed and implemented without a thorough prior analysis (i.e. estimation) of how the system will work once implemented.

V. *Evaluation and final choice.* This is a crucial stage in the process. Here, final decisions have to be taken, obviously, on the basis of the CRP. Often, conflicting interests become apparent and good management and leadership is required to arrive at a wise decision. Once the decision is taken the design phase is ended and the implementation starts.

In the following sections some aspects are discussed in more detail.

**The central role of the learning objectives**

It has been discussed that the design approach to education implies the prior definition of the learning objectives. Also elsewhere, the central role of learning in education has been widely discussed elsewhere. This role can be depicted as in Figure 4.

---

Figure 4: The central role of learning objectives

---

This figure illustrates the intrinsic relation between learning objectives (envisaged results of the designed education), instruction (means in order to arrive at these goals) and the assessment (the verification whether the goals are indeed achieved). The main observation is the central position of the students. As mentioned before, it is their results that have to be defined as learning objectives, rather than the material to be taught. This is in fact the same as the so-called paradigm shift from teaching towards learning, or, in other words: the shift from input oriented education to output oriented education (Figure 5).

![Figure 5: Input vs. output oriented description of education](image)

**Active learning as an effective means to achieve learning outcomes**

Once the central position of the students as well as the envisaged outcomes have become clear, attention should be given to the means to arrive at the goals. As discussed above, there are always more solutions to a problem than just one. In education this means, that several educational modules can be conceived that may lead to the final goal. Since the student plays a key role in education, it is not surprising that those educational modules, that include some form of active learning will usually better meet the requirements as defined in the Course Requirements Program than modules consisting of purely frontal lecturing. Active learning stimulates students to take responsibility for their own learning. Two important methods using active learning are (Graaff & Kolmos, 2003):

- **Project Organized Learning (POL):** students work in project groups on real life problems (cases) in order to solve the problem.
- **Problem Based Learning (PBL):** the learning is triggered by a problem (case), the collaboration aiming a defining learning goals

In both situations are highly responsible for their own learning. The teacher is a process facilitator, rather than the one who ‘transfers’ knowledge. Clearly, this can be related to the previously discussed shift from teaching towards learning oriented education. This is schematically summarized in Figure 6.
The key features for the success of active learning are:
- Freedom for the students to decide on their own learning process
- A clear purpose of all learning activities
- Sufficient attention for communication skills
- Balanced support from technical experts to overcome knowledge barriers

Obviously, the issues should cope with criteria as formulated in the Course Requirements

Example of Active Learning
As an example of active learning we refer to a module designed for first year BSc students in Electrical Engineering at the TU Delft (Rompelman, 1999). This module was designed on the basis of a problem analysis. The result of this analysis the following issues could be identified:

1: Missing elements:
   a) Integration of knowledge areas
   b) Understanding the relevance of courses
   c) Relation with profession of electrical engineer

2: Underdeveloped competencies:
   a) Creativity
   b) Communication
   c) Conceptual thinking
   d) Design ability

It was decided that these, indeed vaguely described competencies could most likely be best developed by group work in whatever form. The educational setting is that right from the beginning of the academic year students are placed in groups of 10. During the entire academic year they work together for four hours per week at the university, where they have a room available with a (internet connected) PC and some simple laboratory facilities. The total study load of the module is about 15% of a year load (8 ECTS credit points). An example of an assignment is the analysis of a CD-player. The following tasks are carries out (the numbers in brackets refer to the issues of the problem analysis mentioned above):
- Identifying the constituting components on the basis of functionalities by discussion and using the white board (2-b, 2-c)
- Disassembling a CD player (1-c, 2-c)

---

• Drawing a final functional block diagram (1-c, 2-1, 2-c, 2-d)
• Identifying which first year courses present knowledge and skills necessary to design the identified functions as well as the entire system (1-a, 1-b, 1-c)
Obviously all activities are related to issue 2-b.

**Conclusion**
The principles of the design of technical systems can be successfully applied when developing and reforming education. It is important to start with a proper definition of the educational problem leading to well defined envisaged learning outcomes. Consequently, a, possibly detailed Course Requirements Program has to be formulated, taking all present and future stakeholders into account (teachers, administrative staff etc. but most of all: students). When it comes to indeed conceiving educational modules, some form of active learning will often be a logical choice taking the Course Requirements Program into account.

**References**


*Fundamentals of Business Engineering and Management*,
Delft University Press

The engineering of engineering education: curriculum development from a designer’s point of view

A first year course in integrative learning: a practical example of 'back to the basics';

Van der Vleuten, C. P.M. (1979)