

# Beyond The Engineering Pedagogy: Engineering The Pedagogy, Modelling Kolb's Learning Cycle

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***Abstract:** Experiential Learning is a modern radical approach of conducting education. Kolb's four stages experiential learning model have been well received since it was proposed during mid 1980's. In this paper, we approach the analysis of Kolb's Cycle from an engineering point of view, where we develop a mathematical model of the learning curve when Kolb's experiential learning cycle is use. Furthermore, we analyse the characteristics of the derived model for example, learning stability and learning robustness. We conclude with set of important characteristics of Kolb's cycle that we could clearly explore after utilizing the control engineering tools. The most important characters are accommodating the uncertainties of the students learning ability. This paper is one of the few trials traced in the pedagogical literature where control engineering methods are applied for studying pedagogical process.*

## Introduction

Constructivist pedagogy is a paradigm that perceives learning as a process of constructing knowledge by individuals themselves rather than passively pouring information in their minds by the teacher (Brown et al 1989; Steffe et al 1995). In constructivism, learning is a continuous journey of meanings searching and knowledge construction. Since constructivism emphasizes the individual's important role in knowledge construction, its strategies in teaching are often called *student-centered instruction*. The psychological works of Piaget left a significant contribution to the constructivist pedagogy, he asserted that learning takes place by active construction of knowledge rather than passive reception of knowledge (Piaget 1978). The main pillar of constructivist pedagogy methods is self experience of learning. The role of experience in learning has been investigated by many and has been found to have a dramatic impact. Farrell and Hesketh suggest that students typically recall about 20% of what they hear, while if they hear and see something done, they may recall closer to 50% of the experience, if they actually do something, such as conducting an experiment or solving analytical problem, they are likely to recall as much as 90% (Farrell et al 2000). Experiential learning (EL) has gained increasing interest in the education field during the last thirty years, especially in the United States. This period has witnessed the birth of many experiential learning models. One of the most important experiential learning model was proposed by David Kolb mid 1980s (Kolb 1984). Kolb, in his 6000+ times cited book (Kolb 1984) has built on Dewey's theory of education (Dewey 1938) and Lewin's field theory in social psychology (Lewin 1942). These works had lead Kolb to develop a four stages learning model in which learning should involve the following phases: "Concrete Experience;" "Reflective Observation"; "Abstract Conceptualization"; and "Active Experimentation". The model is generically called Kolb's experiential learning cycle.

Control Engineering provides a valuable framework, theory, and the tools for modelling physical and technical systems, analysing their dynamical behaviour, and controlling the system for achieving a set of desired objectives. Control system methods have been recently and successfully extended to non-

conventional fields such as biology, economy, and finance. However, they have been seldom used to develop models of pedagogical processes. The key elements of control system engineering are the systematic perception of the process elements and their couplings, the goal oriented objectives of the process and the necessity of measurements and feedback for the purpose of successful achievement of the set objectives. In comparison with pedagogical processes, we find analogy in the following pedagogical elements:

- Learning Objectives (Goal oriented objectives/Reference Signals/Regulatory Control).
- Formative and Summative Assessment (Measurements/Feedback).
- Learning is a dynamic process in general (Dynamical Control Systems).

We think that pedagogical processes can be looked at from control engineering point of view. The latter would offer us a comprehensive theoretical framework and tools for analysing the former.

## Kolb's Experiential Learning Cycle

Kolb suggested that learners must be able to immerse in new experiences (CE), they should have reflective skills and multiple views of observation (RO), they must be able to conceptualize the observations and the experiences by integrating them into theories (AC), and finally they must be able to use these theories for making decisions and solving problems (AE). Hence, effective learners should have four types of abilities; Concrete Experience Ability (CE); Reflective Observation Ability (RO); Abstract Conceptualization Ability (AC); Active Experimentation Ability (AE). The optimal learning takes place when an adequate balance of these four characters is carried out. The combination of the previous four stages is called the Kolb cycle of experiential learning and is shown schematically in Figure 1.

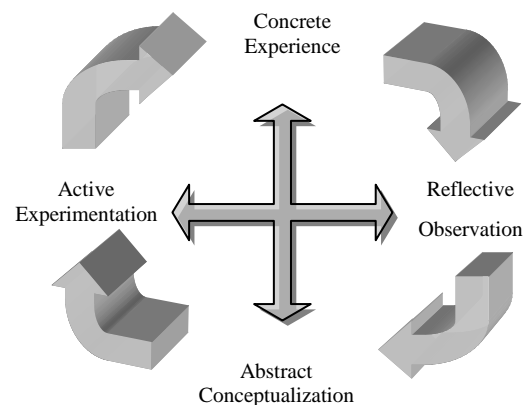


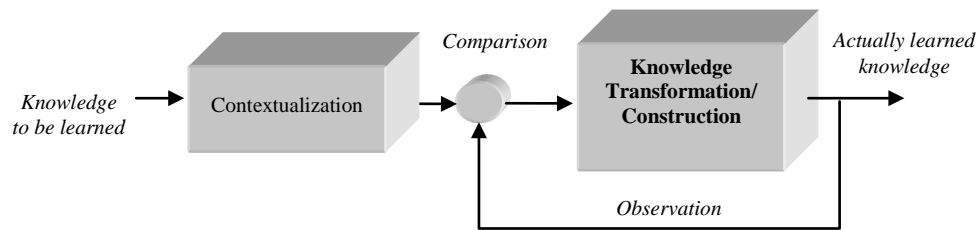
Figure 1: Kolb Experiential Learning Cycle

Kolb proposed that these are the stages of creating knowledge by transformation into abstracts through experience. Learning requires that individuals first should detect, depict, or grasp knowledge, and then a phase of construction should take place to complete the learning process. *This construction is a transformation of the grasped knowledge into the mental model through experiencing this knowledge.*

The vertical axis in Kolb's cycle represents the knowledge grasping dimension, or prehension dimension, by which knowledge can be grasped through Apprehension (the concrete experience extreme) or by Comprehension (the abstract conceptualization extreme), or by mix of both. The horizontal axis represents the knowledge transformation or knowledge construction dimension. The construction can be done via Intention (the reflective observation extreme), or via Extension (Active Experimentation). Kolb's hypothesis of the two dimensional nature of knowledge building, the prehension dimension and the transformation dimension, was drawn from convergent evidences from philosophy, psychology, and physiology. Literature prior to this hypothesis, did not distinguish between grasping and transformation, combining them in one axis. Hybrid combination of the previous elementary modes in the learning process would produces higher and deeper learning levels.

## Control Engineering Model of Kolb's Cycle

Kolb has derived his model based on Lewin's social and pedagogical works (Lewin 1951). Lewin indeed had borrowed the control engineering concepts such as reference signals, measurements, and feedback to develop a four stages model of learning that became later a core basis of Kolb's



**Figure 2: Mapping Kolb's Cycle into Engineering Model.**

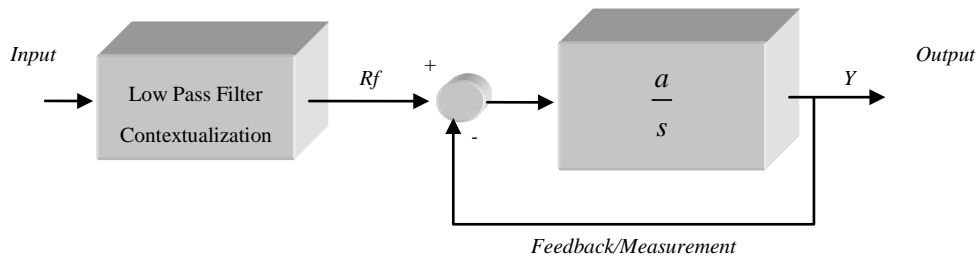
experiential learning theory (Kolb 1984). Lewin considered information feedback an essential element in building a continuous process of goal-directed learning actions. *Lewin and his followers firmly believed that much of an individuals and organizations deficits could be traced to a lack of feedback processes.* Kolb has emphasized many times that learning should be considered as a continuous PROCESS grounded in experience. He defines learning as a *process of constructing knowledge*. In this paper, a return to Lewin and Kolb's utilization of feedback concepts from engineering is proposed with a purpose of mathematically analysing the dynamical behaviour and presenting the advantages of Kolb's experiential learning cycle.

In the modelling course, it is very important to emphasize on the control engineering principle of simplifying the target process in a much simpler model than reality. In many times, the system behaviour is approximated to a linear one. In modelling, we consider the most important aspect that the model is trying to analyse neglecting the other system characters. These main guidelines have proved to be successful in modelling technical control systems, in many times due to the nature of feedback loops which can accommodate model uncertainties. *We draw on these principles when we target modeling Kolb's cycle, hence, simplifying and aggregating many characters into a simpler linear character.*

## Mapping Kolb's Learning Stages into an Engineering Model

Kolb's cycle has four main stages, CE, RO, AC, and AE. The CE stage is reported to be a place of stimulation and attention towards the intended learning outcome (Bailey et al 2004), it represents the exposition to new knowledge or experiences. The concrete experience plays the main role of contextualizing the learning objectives and filtering them among the whole set of other information and sensed variables by the students during the learning phase. It represents the first experience of new knowledge to be learned. The stimulation and the first experience CE stage leads to reflection upon in a form of the question "Why?" for understanding the experienced concrete status. This reflection will transform the perceived knowledge in the CE stage into the conceptual abstraction AC in the learner mind. As the abstracts were implemented in mind, the active experimentation AE can be triggered to test the abstracts. This experimentation will lead to the subsequent phase of knowledge construction via extension and hence to new concrete experience situations of higher order. Therefore a successive cycle of learning will be initiated until the whole set of learning objectives (new knowledge) is achieved. Figures 2 and 3 show a translation of Kolb learning process into engineering and mathematical models.

The "Input" signal represents the learning objectives (new knowledge to be learned) which is corrupted with noise, this noise presents any external informative, sensitive, or cognitive distortion around the intended learning objectives. The CE would work as a filter contextualizing the learner into a filtered set of learning objective he or she faces for the first time. Once the learner is exposed to this new knowledge via concrete experience, a reflection phase would construct a new conceptual mental models (or abstracts). The process of constructing new models would be associated with active experimentation AE of this new models by the learner. The reflection and active experimentation would lead to assimilating new models in the learner mind and hence accumulating newer knowledge (Piaget 1977). This construction phase is modeled mathematically via a constructor (or



**Figure 3: Mapping Kolb's Cycle into Mathematical Model.**

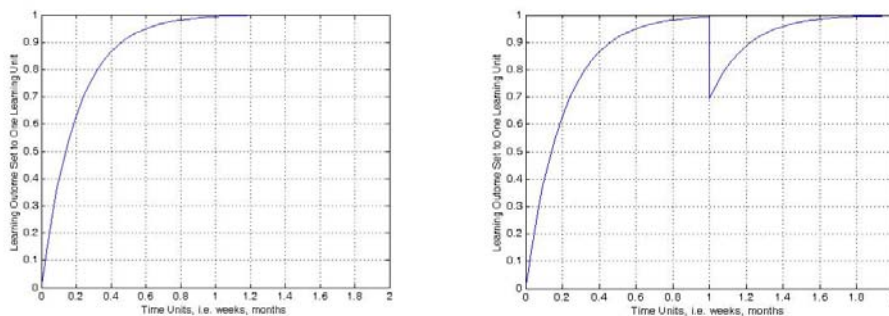
integrator/accumulator). The integrator action represents mathematically any accumulating phenomena such as tank filling or capacity charging. The signal “Output” in Figure 3 represents the new constructed abstracts of knowledge in the learner mind, i.e. what have really been learnt so far. As soon as the learner has constructed new knowledge (i.e. learned something new), the observation phase (measurement and feedback) will compare the new level with the learning objectives set. If there is still something to be learned, the learner will find him/herself exposed to a new higher order concrete experience, hence a new knowledge construction (accumulation/integration) phase will take place. The loop keeps on running until the whole set of learning objectives are met.

The model shown in Figure 3 can be written in state space as follows:

$$\frac{dx}{dt} = -\frac{1}{a}x + Rf \quad (1)$$

$$Y = x$$

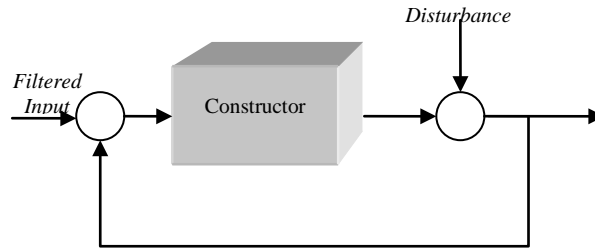
Where  $x$  is the internal state presenting the accumulated knowledge level,  $Rf$  is the filtered reference signal or input representing the set of intended learning outcomes,  $Y$  is the actually learned or constructed knowledge.



**Figure 4: Simulation of Accommodating Learning Disturbances (Right) .**

### **Kolb's Model is Stable and Able in Achieving The Learning Outcome Despite Disturbances**

One interesting point that the mathematical model of Kolb's cycle reveals is the stable nature of learning process when Kolb's model is admitted in learning. The model derived in (1) represents a first order integrator with feedback, this model is stable. Stability means that Kolb's model can bring the learning outcomes to the set point defined in the input as shown in Figure 4 (Left). Hence, the learner will be able to reach the learning objectives set when learning involves balanced contribution of Kolb's learning stages.



**Figure 5: Disturbance Rejection Character**

Furthermore, The model in (1) is able to reject constant disturbances. In mapping this to the learning process, it means that when the learner is exposed to a disturbance during the learning period such as loss of some learning outcomes, or non validity of some learning outcomes due to a change in circumstances; the learner will be able to overcome these and bring the learning outcomes again to the learning objectives set. Figure 4 (Right) shows simulation of a Kolb based learning process where a loss of 30% of the achieved learning outcomes occurred after one learning time unit, however, the learner could recover this loss completely and could bring the learning outcomes again to the set of objectives. Figure 5 shows a schematic diagram of learning process with disturbance.

### Kolb's Learning Model Assists in Accommodating Learning Uncertainties

The closed feedback loop shown in Figure 3 has an inherent robustness characteristic against model uncertainty; the uncertain model version of system given by (1) can be written as follows:

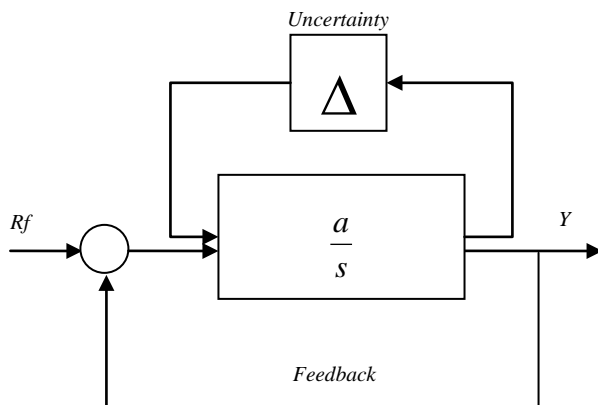
$$\frac{dx}{dt} = -\frac{1}{a}(x + \Delta x) + r \quad (2)$$

$$Y = x$$

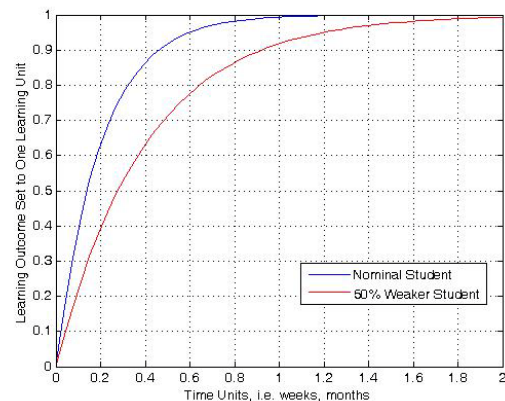
Where  $\Delta x$  represent the uncertainty. Figure 6 shows the block diagram of the Kolb based learning process with learner uncertainty.

The model uncertainty may represent an uncertainty in one student's ability of learning, *a weaker student than the average can be modeled with an uncertainty term.*

To show the robust characteristic of Kolb model, we simulate the nominal student learning model



**Figure 6: Kolb's Engineering Model with Uncertainty**



**Figure 7: Learning Dynamics, Nominal vs. Weak Learner**

given by equations (1) and compare it with the simulation of a weaker student by setting  $\Delta x = 0.5x$  in the uncertain model given by (2) (i.e. the weak student has about half learning capabilities of the nominal students). Figure 7 shows the simulations results; we notice that in spite of the half capability of the weaker student, she/he is able finally to reach the learning objectives. This enhanced performance is mainly due to the feedback loop and the continuous work on bridging the gap between the learning outcome and the learning objectives.

## Conclusion:

In this paper, a mathematical model of Kolb's experiential learning cycle has been developed, the model is one of the few pedagogical models that are built with the assistance of control engineering techniques. The study of the model revealed two important characters of Kolb cycle, first of all it is stable and guarantees reaching the learning objectives. Secondly, it is robust and can accommodate learner learning weakness through continuous process of the feedback loop repetition. This paper adds an engineering quantitative evidence to the supportive pedagogical literature of Kolb's experiential learning theory.

## References:

- Baiely M, Chambers J, 2004. Using The Experiential Learning Model to Transform an Engineering Thermodynamics Course. Proceedings of the 2004 Frontiers in Education Conference, 20-23 October 2004, Savannah, Georgia, USA.
- Brown S, Collins A, Duguid P 1989. "Situated Cognition and the Culture of Learning". Educational Research 18, 32-42.
- Dewey J. (1938/1997). Experience and education. Macmillan.
- Farrell S, Hesketh, R P 2000. An Inductive Approach to Teaching Heat and Mass Transfer. Proceedings of the 2000 American Society for Engineering Education Annual Conference & Exposition.
- Kolb DA 1984. Experiential learning: experience as the source of learning and development. Prentice-Hall.
- Lewin K 1951, Field Theory in Social Sciences. New York: Harper & Row.
- Piaget J 1978. The Development of Thought: Equilibration of Cognitive Structures. Blackwell.
- Richardson V 2003. Constructivist Pedagogy. The Teachers College Record.
- Steffe LP, Gale JE 1995. Constructivism in Education. Lawrence Erlbaum Associates Inc.
- Tennant M. Psychology and Adult Learning. Second Edition. London: Routledge, 1997.

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