A NEW LEARNING MODEL DESIGNED TO SUPPORT THE DEVELOPMENT OF SHARED UNDERSTANDING OF NEW COMPLEX SITUATIONS, PROBLEMS, AND SYSTEMS

B. Lennartsson[1], R. Ekinge[2], E. Sundin[3], K. Davidson Söderman[4],

[1]Linköping University, Linköping, Sweden
benle@itn.liu.se
http://www.itn.liu.se/~benle/

This paper presents the objective, design, implementation, execution, and evaluation, of a new learning model focusing on the capability to understand and solve new problems and to answer new questions. This model has inherited ideas from Problem Based Learning, Project Organized Curricula, Double-Loop Learning, Reflection-in-Action, Socratic Leadership, Team Learning, and others. The core component is the emphasis on the development of a new, shared understanding in a team. This is quite different from the traditional goal where the individual student or professional engineer is trained to be able to remember and rephrase contents of lectures or textbooks or to present solutions to standardized problems.

1 Introduction

The authors have been involved in the development and execution of a wide range of educational and training programs in different situations and environments for a long time [1-9]. The experience ranges from elementary school teaching via competence development for teachers and principals, undergraduate and graduate programs in engineering and management, university leadership and management, training programs for engineers and managers in industry, to corporate and global industrial management. In this wide spectrum we identified several situations and objectives, where a new learning model had to be introduced to meet the specific needs, but in many of these situations the cornerstones have been the same.

1.1 The Industrial Needs

In several longitudinal case studies in industry we have identified some requirements on managers and engineers, and some general capabilities and leadership attributes needed. For the development engineers we have defined the new requirements, compared to the traditional ones, as [2]:

- capability to ***learn new things*** is more important than ability to remember established facts
- capability to ***communicate and to co-operate*** is more important than individual brilliance
- capability to ***understand totality and interdependencies*** is more important than expertise in a narrow area
- capability to ***ask question and be pro-active*** is more important than ability to follow detailed instructions

Some of these attributes or capabilities may be trained, or at least prepared for, in the regular university curricula. Others may be such that several years of experience are needed to be able to approach mastery.

However, it is our strong belief, that the general attitude towards learning fostered at school and at university is a very important ingredient for the development of the mind of the manager or the engineer. Traditional teaching methods may be sufficient to achieve traditional goals: to be able to remember contents of books and lectures, and to be able to use existing tools in familiar situations.

1.2 Models of Knowledge, Understanding and Capability

Aristotle [10] used a model of knowledge based upon three components, where *episteme* was the declarative one, the ability to remember facts. The second component, *techne*, is the practical skills, ability to use tools and to make things. The third component, *phronesis*, is the next level of capability: to be able to interpret and understand new situations, to be able to understand and predict consequences of different actions in this new situation. For this some degree of wisdom is needed.

We would like to introduce yet another level of capability, a level above the wisdom and the ability to interpret new situations and understand consequences of different actions. This higher level is the capability to have power and force to really act, to have the charisma and enthusiasm needed to get support from the environment. In short, the capability to make things really happen and real change to occur! To 'be pro-active´ and to 'be understood´, Covey [11].

1.3 Models of Learning

So, if we look at the different levels of knowledge or capability, the basic declarative level is straightforward. Read books, listen to those who know, and remember. Also the ability or skill to use models, methods, and tools is simple to achieve by means of training, even if sometimes a large amount of hard work is needed. To change your basic mental models, your beliefs, your values, and your behavior is much more painful.

The development of self confidence, to achieve faith in new and unknown situations, to be able to analyze and define new problems, to be familiar with finding solutions to the new problems, are all capabilities not developed or even supported in the traditional transmission view of education. Such capabilities are not transferred from lecturer to students in lectures, or from author to readers of a book; a much deeper interaction between action and reflection is required. There is always a resistance to change, Fig. 1. If not, it is no real change!

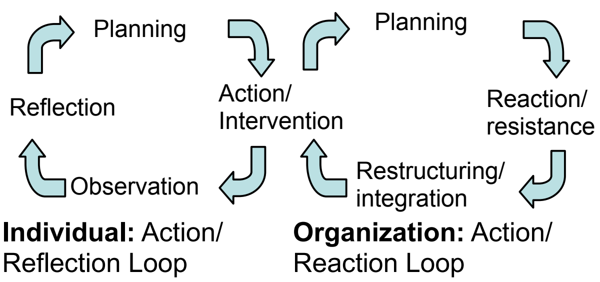

Figure 1: A variant of the Double Loop Model

So we have developed a learning model designed to meet the new needs. The most important components are the Socratic leadership [8] and the systematic use of interaction between action and reflection [12] to enable a shared understanding of complex problems and situations. Socratic leadership means that we present to the students selected questions, situations and problems rather than answers or solutions. The second component is based on the observation that today most problems and questions are such that a combination of views and experiences from many different areas will be needed to enable the evolution of solutions and answers. Hence, in such situations co-operation in heterogeneous or cross-functional teams is a key issue. As engineering is aiming at the development of *new* systems and solving *new* problems, the establishment of shared concepts and shared mental models in heterogeneous teams is a major concern. What this means in our model will be explained in examples below.

1.4 Related Approaches

There are many different approaches around, and we have borrowed ideas from many of them. We believe in taylor-made approaches tuned to the particular situation at hand. Our major influences are from: PBL, Problem-Based Learning, [13-15], Project Organized Curricula in engineering [16]. Double-Loop Learning, Reflection-in-Action, and The Learning Society [17], [18], Learning Organizations and the Discipline of Systems Thinking [19], Model of Personal Action [20], Multi-Level Self-Management [21], Individual/Social Learning [22], Triple-Loop Learning [23], Transformational Coaching [24], and Complex Instruction [25].

Compared to all these efforts we are focusing more on the development of *new* understanding and approaching *complex* problems. As a consequence, for us the development of new, shared understanding in the group is more important than studies of literature, and so are also participatory goal setting and evaluation. For this we have used the portfolio concept [26-28].

2 Experience from Selected Areas

The need for change in education as indicated in the previous section is very demanding indeed. We don't claim we have been able to meet the very ambitious requirements. However, we do believe we have taken some small steps in the appropriate direction. In this section we will present what we have done in the past and what we have learned from that.

2.1 Public School Management

Since 1998 there has in the City of Katrineholm in Sweden been a training program for the principals of the 18 public schools in the city. This program is based on our learning and training model. Within each school the principal has his/her team of 30-40 teachers.

The school leadership has since around 1991 been very demanding in Sweden due to an entirely new organizational framework. The program in Katrineholm is intended as a means to support the principals in their difficult role, and the model used for the principals can then be used by them in the next step for the training of their own managing teams.

In parallel to the program for the principals there is also a support of the management team of each school. The approach to simultaneously work with the principals and their management teams seems to be very successful. It is aiming at enabling, or enforcing, change in the organization and a method to really prepare the organization and its members for change as well as for cooperation and support. Preliminary we can conclude that the impact has propagated also to the next level, from the management teams at each school to the teams of teachers. The approach is similar to that at for the industrial training program at Whirlpool presented below.

2.2 Experience from the use of PBL for a new Engineering Curriculum

Linköping University has since 1986 used PBL [23-25] as a general model in nursing and medicine. PBL had also been used in a few courses in engineering when it in1995 was selected as a universal model for a new 4.5 years MSE program in Information Technology. In this context PBL means a fairly strict procedure following the nine steps, Fig. 2.

1. Clarify terms and concepts in the case
2. Perform a brainstorming session
3. Structure the results of the brainstorming
4. Define one to three problems/issues
5. Define the learning needs
6. Collect information
7. Apply the knowledge to the problem(s)
8. Apply the new knowledge to the case
9. Evaluate your activities

Figure 2: The nine steps of PBL

We found that the engineering students experienced some difficulties not mentioned by the students in medicine. We also noticed that the results in the initial courses in calculus and algebra were remarkably weak. The PBL approach to start from a problem or a situation, sufficiently general to be understood by the students and, from there, look for appropriate mathematical tools and methods was not supportive. Before the students could look for tools and methods they needed an understanding of the contents and the structure of the mathematical toolbox.

So we learned that there are some very important differences between studies in medicine and in engineering [3]. In medicine the knowledge required was of the *episteme* type, to read text and remember the contents. The discussion in the tutorial group was about selection of text to read and about exchange of reactions after reading. The students in engineering needed time to assimilate the mathematical models and concepts, mainly individual processes. They also needed time to practice individually with the models and methods, and to develop the skills to use them to solve engineering problems. For the students in medicine there were no similar requirements.

Later in the studies when the basic concepts and models were settled, another very important difference between medicine and engineering manifested itself. In medicine, it is assumed that once the problem is defined, the solution is available in the library. The engineering students, on the other hand, are trained to create or develop *new* systems or *new* components. The design team must develop the solution to the problems. So, in the PBL model, Fig. 2, the tutorial group in engineering can be used not only for the definition of the learning needs, but also for ´real learning´, *i.e.* the development of *new* knowledge in the tutorial group.

So, to summarize, strict use of PBL in engineering education turned out to be very helpful for the integration of material from different areas, as well as for the motivation and social context for the subject oriented learning. However, PBL as it was used did not support the individual development of the skills to use mathematical models, methods, and tools or the understanding of the basic structure within a discipline. A better communication of the goal could have eliminated some of the weaknesses.

2.3 Learning and Training Models in the Industrial Environment

For several years we have had a close cooperation between Linköping University and Whirlpool, in particular Global Development within the Microwave Oven Business Unit. In Global Development s*ocratic leadership* and *team learning* have been favorite models. In the early nineties Whirlpool Corporation needed a new Electronics Strategy and, independently, the Product Development Centers for all product categories were reorganized. It was decided to implement an organization reflecting the product structure, with: *Platforms* and *Functional Modules*. Early in 1996 it was recognized that a successful implementation needed support from an intensive training program. We were involved and had the opportunity to use and test our ideas when reorganizing the development centers in Europe [4-6], and [8].

In this kind of research you can't quantify results in numbers in a meaningful way and you can't use controlled experiments and compare between groups. However, the participating engineers and we experienced a very clear impact on the way of thinking. The evaluation of the effort was positive with comments as:

- "*It is a new way to think about the job. I had difficulties to understand in the beginning*"
- "*I saw very often that there are different points of view*".
- "*We have touched very deep and profound subjects which need "time together*".
- "*Most of our problems are non-technical in nature, very much reflected in the Cases*".
- "*We needed help by the tutor very often, but we have learned a lot*".
- "*A clear direction to improve our capability, and company to be effective has been identified*."
- "*We are at the threshold of a very interesting development. The implementation of the program can start a revolution*"

The size of the tutorial group was 8-10 persons, and the whole development organization around 100.

Lars Taxén has in a Ph.D. thesis project studied and introduced models in the very large scale organization at Ericsson with coordination of organizational learning in projects with over 10 000 persons involved in over 20 countries. The basic models for learning and for leadership are similar, but in the very big organization, co-ordination of all efforts tends to be the main issue.

The Whirlpool experience is mainly that the model we used, Socratic leadership plus PBL-like team learning, turned out to be a very powerful tool for top-down deployment of acceptance and use of new models and methods in an organization. This could be seen as a paradox as one common argument for the use of PBL and related models is their intended support for the development of critical thinking and self-directed learning.

The Ericsson experience is primarily the importance of the establishment of a shared understanding of new basic concepts and their meanings and interrelation. This establishment turned out to be highly dependent on participation. A shared interpretation of even very basic concepts as *requirement* and *function*, need to be established in a participatory process to avoid misunderstandings. When discussing entirely new systems and new situations, you can't just distribute definitions of the terms as there is in this context no shared understanding of any fundamental concepts. A conclusion from the Ericsson project is that the establishment of new, shared concepts has to be iterated many steps before there is a match in the organization between their different interpretations and use, and the needs in the daily work. Hence, a powerful flexible support for dynamic visualization of the shared concepts and their relations and attributes is a key to success.

3. Our Current Position: A System Integration Course

We have used our learning model, based on the experience and ideas we have, and designed a sequence of programming courses [9] for Electronics Design students. The major differences between our model and the traditional ones are:

- we supply questions and problems rather than answers and solutions (Socratic leadership)
- we leave to the students to suggest a definition of the requirements on the system to be developed (participatory goal setting)
- we leave to the students to decompose total system into subsystems, to assign subsystem design and implementation to subgroups of 6 students (participatory project organization)
- we leave to the students to test the subsystems and integrate and test the total system (systems thinking, system test and integration)

- we leave to the students to formulate and verify the individual ambitions and to verify the results in terms of learning (portfolio principle)
- we are "fertilizing" the process by being available, giving support and feedback, and even intervening in case a group is very far away from its track

The experience is best illustrated by some student reactions:

- *One thing that just occurred to me recently is that there was no regular teaching at all in this course! Everything is based upon guidance and general support. This is highly fascinating!*
- *Before this course I was afraid of trying something new, if I was not sure about the outcome. Now I dare do such things. This has changed my life!*

Before any student gets a pass, or higher grade, he/she has to convince us, normally in oral discussion, that he/she has the capability and understanding required. So far it is quite clear that the results are far better than we would dare require if we had prescribed the different levels in detail. They have also learnt much more also of the purely technical contents than they would have done if we had fed them with information selected by us and in the same pace for all of them.

4 Discussion and Conclusions

It is our strong belief that in a global and increasingly complex world, we must meet the very ambitious requirements on our educational system listed in the introduction. For development engineers in industry the system requirements will change considerably during a typical development project [29] and the development teams themselves must have a holistic understanding and capability to act and respond to new technology and competitor moves. At the same time the efforts in the whole organization have to be coordinated [12]. We don't believe that the traditional transmission model is adequate in this situation. This model is based upon the idea that the major role of our educational system is to transfer the accumulated knowledge and understanding from one generation to the next. We suspect, however, that what the current engineering students will need in their future career is today mainly unknown to their teachers.

We claim, based on indications from the use of our learning model, described in more detail in [1-9], [12], that the model is highly beneficial for the development of the new capabilities of the students. And we are loosing nothing as, as a side effect, they will also learn and understand more also of the traditional contents: system development and programming distributed software systems.

Acknowledgement

Our action research has been possible thanks to the totally open attitude we have experienced from our industrial partners, in particular Whirlpool Corporation. The research has been funded by NUTEK, The Swedish National Board for Technical Development, and by KK-stiftelsen, The Knowledge Foundation.

References:

[1] Lennartsson B., Davidson K.: Experiences from Direct Application of the PBL Method in Industrial Training and Organization Development. Presented at The University of Maastricht's 20th Anniversary Conference: Placing the Student at the Centre. Maastricht, The Netherlands, Nov. 20-22, 1996.

[2] Lennartsson B., Davidson K.: Team Understanding Capability - The New Requirement on Higher Engineering Education. Proceeding of the Second International Conference on Teaching Technology at Tertiary Level. Stockholm, June 14-17, 1997.

[3] Lennartsson, B.: Why there are different teaching preferences in different disciplines. Proceedings of The International Conference on Project Work in University Studies, Roskilde, Denmark, September 14-17, 1997.

[4] Davidson, K, Lennartsson, B: Team Learning Capability - A Strategy to Master Complexity and to Achieve Flexibility. Proceedings of The 7th World Conference on Continuing Engineering Education, Torino, Italy, May 1998.

[5] Cederling, U., Ekinge, R., Lennartsson, B., Taxén, L., Wedlund, T.: A Project Management Model based on Shared Understanding. Proceedings of Management Minitrack in the Organizational Systems and Technology Track of the Thirty-third Hawaii International Conference on System Sciences (HICSS-33), January 4-7, 2000.

[6] Ekinge, R., Lennartsson, B., Taxén, L.: Organizational Knowledge as a Basis for the Management of Development Projects. Presented at Discovering Connections: A Renaissance Through Systems Learning Conference. Dearborn, Michigan, September 24-27, 2000.

[7] Lennartsson, B., Sundin, E. Fronesis - The Third Dimension of Knowledge, Learning, and Evaluation. Proceedings of the 31st IEEE and ACEE joint Frontiers in Education Conference (FIE 2001), October 10-13, 2001. Reno, Nevada.

[8] Ekinge, R.: Socratic Leadership and Three-dimensional Change. Accepted for the IEEE Conference IECM-2001. Conference cancelled due to the WTC events September 11th, 2001.

[9] Lennartsson, B., Sundin, E.: Experience from a Course Aiming at Understanding System Development with Focus on System Design and Integration. Proceeding of Frontiers in Education Conference (FIE 2002). November 6-9, 2002. Boston, MA, USA.

[10] McKeon, R. (Editor): The Basic Works of Aristotle (Modern Library Classics). Princeton Review; ISBN: 0375757996; Reprint edition Sept., 2001.

[11] Covey, S., R.: The Seven Habits of Highly Effective People. 1989.

[12] Lars Taxén: A Framework for the Coordination of Complex Systems' Development. PhD Thesis. Linköping University, Dep. of Comp.&Inf.Sc., March 2003.

[13] Boud D., Feletti G. (eds.): The Challenge of Problem Based Learning. London: Kogan Page Limited.

[14] Albanese, M, A, Mitchell, S: Problem-based Learning: A Review of Literature on Its Outcomes and Implementation Issues. Academic Medicine. Vol. 68. No 1. Jan. 1993. pp 52-81.

[15] Hadgraft, R., Holecek, D.: Towards total quality using problem-based learning, Int. J. Eng. Educ., 11 (1) 1995, pp.8-13.

[16] Kjersdam, F., Enemark S.: The Aalborg Experiment - Project Innovation in University Education. Aalborg University Press 1994. ISBN 87-7307-480-2.

[17] Argyris, C., Schön, D.A.: Organizational Learning: A Theory of Action Perspective. Reading, MA. Addison-Wesley 1978.

[18] Argyris, C: Reasoning, Learning and Action. San Francisco: Jossey Bass. 1982..

[19] Senge, P.M.: The Fifth Discipline: The Art and Practice of The Learning Organizations. Doubleday. New York, 1990.

[20] Edwards, J., Butler, J., Hill, B., Russel, S.: Perople Rules for Racket Scientists. Samford Research Associates. Samford, Australia, 1997.

[21] Cheung, W., M.: A Study of Multi-level Self Management in School. The Chinese University of Hong Kong Graduate School - Division Of Education. PhD Thesis, Aug 22, 1996.

[22] Salomon, G, Perkins, D. Individual and Social Aspects of Learning. Review of Research in Education, Volume 23, 1998.

[23] Flood, R.L., Romm, N.R.: Diversity Management: Triple Loop Learning. ISBN: 0-471-96449-2. July 1996.

[24] Hargrove, R.: Masterful Coaching: Extraordinary Results by Impacting People and the Way They Think and Work Together. John Wiley & Sons; ISBN: 0787955655. August 1995.

[25] Cohen, E.G., Lotan, R.A. (2003): Equity in heterogeneous classrooms. In J. Banks & C. Banks (Eds.), Handbook of Multicultural Education (2nd Edition). New York: Teachers College Press.

[26] Vavrus, L, G., and Collins, A. (1991): Portfolio documentation and assessment center exercises: A marriage made for teacher assessment. Teacher Education Quarterly, 3(2), 12-29.

[27] Perkins, D: Smart Schools: Better Thinking and Learning for Every Child. New York, 1992: The Free Press. ISBN: 0028740181.

[28] Cole, D.J., Kick, F, Mathies, B., Ryan, C.W.: Portfolios across the curriculum. Corwin Pr, October 1999. ISBN: 0761975349.

[29] Taxén L.: A Strategy for Organisational Knowledge Evolution. EMRPS'99, (Enterprise Management and Resource Planning Systems: Methods, Tools and Architectures), Venice, Nov 1999.

---

[1] Lennartsson Bengt: Prof. in SW Eng., Dept of Sc. and Tech., Campus Norrköping, Linköpings Univ.. Ph.D.(1974) MW Theory&Tech, Chalmers Univ. of Tech. Head of Dept of Comp.& Inf. Sc. Linköping Univ. (1983-1990) and CS&EE Luleå Univ. of Tech. (1999-2003).

[2] Ekinge, Roland: Global Devel..Mgr MW Ovens, Whirlpool (1997-). Devel.Mgr Electronics, Whirlpool Europe (1995-97).PhD (1972) MW Theory&Tech. Chalmers Univ.Tech.

[3] Sundin, Evabritt: Superintendent, Norrköping Public School Office. BA (1973) Örebro Univ.

[4] Davidson Söderman, Kristina: Consultant PBL Competence AB, Med.Lic. (2002) Social Med., Linköping University