THE MODEL RAILROAD AS AN EXAMPLE AVOIDING TACIT KNOWLEDGE IN MICROELECTRONICS STUDIES

Wiebke Schwelgengräber, Ralf Salomon and Ralf Joost

Department of Computer Science and Electrical Engineering, University of Rostock, Germany

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Abstract: Even though neither teachers nor learners are running for tacit knowledge, it is omnipresent even in engineering disciplines, such as electrical engineering and computer science. This paper is about a problem-based learning environment, the model railroad project that is being developed at the University of Rostock. Two case studies, done in the Summer Term 2009, indicate that this problem-based learning environment can indeed support the students in their studies.

1 INTRODUCTION

Tacit knowledge is an omnipresent phenomenon in almost all teaching environments (Gräsel and Mandl 1999a, p. 54). It might come to a little surprise that this problem is also very present in rather practical sciences, such as electrical engineering and microelectronics: even though these disciplines are about physical entities, knowledge is presented on a rather theoretical level.

In the fields of electrical engineering and computer science it can be frequently observed that students have severe difficulties in applying theoretically learned knowledge to practical (real-world) problems. For example, even though the students know the mathematical model of a simple DC motor, they cannot explain the underlying physical working principles nor can they configure some appropriate controlling circuitry.

Section 2 briefly reviews the pertinent literature on tacit knowledge. According to this review, previous research has argued that for the avoidance of tacit knowledge, it is important to consider both the learner and its learning context. Previous research has already proposed the concept of *problem-based learning* as a relief to this problem: it is a learning and teaching environment that integrates theoretical concepts and practical applications by its very nature. It thus gives the learner the opportunity to embed any new theoretical concepts into practical (real-world) problems. Since this paper is about a particular problem-based learning environment, Section 2 summarizes some of the existing case studies as well as some of its core principles.

In order to improve the learning efficiency in electrical engineering and computer science at the University of Rostock, the authors have instantiated its own problem-based learning environment, the model railroad project, which is described in Section 3. Because of its design, this project offers tasks as diverse as simple wiring, attaching light bulbs, developing switch controllers, and configuring field-programmable gate arrays.

Even though the model railroad project is still under construction, it has already been used in several teaching activities. Section 4 presents two case studies that have recently been done. In these case studies, two groups of students have developed a wireless train controller as well as an advanced switch controller board. Both case studies demonstrate that the model railroad project is suitable to include all the various stages (activities) relevant to problem-based learning.

Section 5 presents an evaluation of the two case studies described in Section 4. This evaluation suggests that the model railroad project is not limited to selected teaching topics but suitable as a platform of rather general interest, since it allows for the implementation of various teaching concepts and methods. Finally, Section 6 concludes this paper with a brief discussion.

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2 PROBLEM DESCRIPTION: TACIT KNOWLEDGE IN ENGINEERING

This section discusses the concept of *tacit knowledge* and some reasons of its occurrences. As a working hypothesis, this section adopts the view that *problem-based learning* can be very effective for avoiding tacit knowledge.

Tacit Knowledge is defined as passive, non-applicable knowledge (CTGV, 1990, p. 2; Gruber and Renkl, 2000, p. 155; Gruber et al., 2000, pp. 139-140). In other words, tacit knowledge is something that is sitting in the brain but cannot be used for anything useful. In that view, tacit knowledge is a waste of resources: it takes time for learners and teachers, it occupies nerve cells, and it gives the illusion of knowledge, even though it should be considered just noise.

It might come to a surprise to some readers that tacit knowledge is an issue even in engineering disciplines, such as computer science and electrical engineering. These disciplines are on physical entities that provide a real-word context, which should help the learner acquire the presented information. But obviously, a significant amount of information is presented in terms of symbols, equations, and definitions without providing any link to previously acquired knowledge or to specific real-world problems; particularly real-world problems would give plenty of opportunities for exercises and routines.

Previous research has provided several explanation models of how and why tacit knowledge develops. Among those avenues, these models have been looking at meta processes, structural deficits, and situated cognition (Gruber and Renkl, 2000, p. 164; Law 2000, pp. 253-255; Gräsel and Mandl, 1999b, p. 4, Mandl et al. 1994, pp. 170-175).

Situated Cognition is based on instructional approaches (CTGV, 1990; Gruber and Renkl, 2000, p. 166) and assumes that learning is a process that not only depends on the (teaching) input but also on the learner's context (Gruber and Renkl, 2000, p. 167). In other words, situated cognition also considers the learner’s activities and interactions as well as the learner’s environment, which are all very important to the learning process (Law, 2000, p. 257).

Since the existence of tacit knowledge is not a recent phenomenon, previous research has also proposed some reliefs. Among those are inquiry learning, experimental learning, constructivist learning and problem-based learning (Kirschner, Sweller, and Clark, 2006, p. 75), with the latter being the focus of the remainder of this section.

Problem-based Learning, also known as PBL, is one of those reliefs proposed against the development of tacit knowledge. Essentially, a problem-based learning environment provides *complex* and *authentic* problems to the learners. In this approach, complexity should help the learner construct mental models in order to embed previously learned “facts” into the semantic networks the learner has already established, and authenticity should be both motivationally and emotionally stimulating.

Problem-based learning environments help avoid the development of tacit knowledge in several ways. For example, PBL students more often use resources, such as libraries and literature, and also appear more competent in investigating and searching of information than their traditional learning classmates (Vernon and Blake, 1993, as referenced in Zumbach, 2003, p. 53), they feel less stress in self-regulated learning (Moore-West et al., 1989, as referenced in Zumbach, 2003, pp. 54-55), and they exhibit better problem-solving strategies due to their ability to better utilize hypotheses and background information (Hmelo, 1998, as referenced in Zumbach, 2003, pp. 62-63). Furthermore, PBL students put more emphasis on developing a deeper understanding rather than rote learning (Coles, 1990; Newble and Clark, 1986, as referenced in Zumbach, 2003, p. 53).

Kirschner, Sweller, and Clark (2006) interpreted the studies presented above in a less positive way, and claim that PBL is actually less inefficient, because of the minimal guidance during the learning process. In light of this statement, Strobel and Barneveld (2009) analyzed several studies in a meta synthesis according to possible PBL-inefficiencies. They stated that problem-based learning is more effective than traditional classrooms with respect to increasing the transfer of knowledge (Strobel and Barneveld, 2009, pp. 53-55).

In general, a problem-based learning environment consists of the following core principles (Zumbach, 2003, p. 20):

a) The students can learn in authentic situations and on close-to-reality problems, which initiate the processes of knowledge elaboration,
b) The students can learn in small groups such that all members are motivated to discuss problems, solutions, and methods,

c) Tutors may support the formal organization and the problem-solving processes, and
d) Resources, such as specialized technical literature, facts presented by the tutor, and models, should be available in order to assist the students in their additional learning processes.

3 THE MODEL RAILROAD

This section presents a brief description of the model railroad project. It was launched, because the authors have experienced several instances of tacit knowledge in many lectures and on all levels. Due to its origin, the model railroad project is intended to mainly help computer science and electrical engineering students.

Because of this intention, the three major design goals are (technical) functionality, flexibility, and simplicity. Furnishings, such as landscaping, tunnels, bridges, mountains, trees, lakes, cars, etc., which are a main focus of most home-owned model railroads, are less important or not suitable, since they might interfere with the intended technical experiments.

Due to space limitations in the laboratories, the project employs trains and tracks of size N, i.e., a scale of 1:160. The tracks are mounted on a board of 1m x 3m in size. Figure 1 provides a fairly good overview of the model. From the figure, it can also be seen that the model basically consists of two parallel circles, two main railroad stations, several side tracks, as well as an elevated plateau. The very many switches and crossings allow for a large variety of operational alternatives.

Figure 1: Overview of the model railroad project.

In contrast to most privately owned model railroads, the present project has employed a digital control mode of operation by means of the digital command control (DCC) protocol (NMRA, 2007). The digital control has the following advantages: every train can assume its own speed, thus playing is much more fun, and it allows for several exercises with the focus in micro electronics. Furthermore, a digitally controlled model can be connected to a PC, which offers plenty of software exercises.

To the technically oriented reader, it should be obvious that the model railroad can be used as a problem-based learning environment, since it is on physical entities by its very nature. This environment offers exercises as diverse as simple wiring and soldering, designing switch controllers, designing controller boards based on micro controllers and/or field-programmable gate arrays, designing wireless motor controls, developing communication protocols, and designing graphical user interfaces.

4 CASE STUDIES

This section presents two case studies that were done in the summer term 2009 and in which the model railroad was used as problem-based learning environment. According to Zumbach (2003, pp. 22-23), every case study proceeded in three steps: (1) problem presentation and discussion, (2) individual and collaborative learning phases, and (3) final discussions. It might be mentioned that in both case studies, the students had to complete a rather complex task. As a consequence, they had to work in small teams, i.e., they had to cooperate.

4.1 Case Study 1: Wireless Train Control

In order to extend the operational capabilities, the goal of this case study was to develop a wireless train controller. This task included the development of a wireless communication (based on ZiggBee), the actual motor control, a link between the motor control and the communication, as well as an appropriate communication protocol.

Three students participated in this case study. They were all regular electrical engineering students. Two of these students were of age 22 and in the forth semester, and the third student was of age 27 and in the seventh semester.

Problem Presentation and Discussion. This case study started with a kick-off meeting in which the students were presented with a brief and rough description of the overall task and its goals. Then, the students entered a self-managed discussion and brainstorming phase. In this phase, the students first divided the task into three subtasks, i.e., communication, motor control, and speed sensor as well as project support by means of a Wiki. Then, they developed a fine-grained specification of the entire project as well as the sub-projects, and they arranged educational objectives. This process was supported by the tutor.

Individual and Collaborative Learning Phase. During the following eight weeks, the students frequently switched between individual work and group meetings. In the latter, they presented their progress, discussed problems as well as possible solutions, and organized the subsequent steps. During that time, the students used the Wiki in order to document their work and to reflect their learning process.

Final Discussions. Finally the students discussed, reflected, and presented results referring to the problem and the educational objectives in an assignment paper by using the Wiki and by participating in a survey. Furthermore, to increase meta cognitive competencies, the students' discussion included some reflections about the individual learning processes to make their learning strategies and methodical actions aware.

4.2 Case Study 2: Switch Controllers

The second case study was about the development of an intelligent switch controller. The controller was expected to offer the following features: (1) connections to a large number of switches, (2) advanced control features, such as puls-width modulation and blinking, and (3) integration of at least a USB (universal serial bus) communication interface.

Again, this task was too complex in order to be completed by just one student in the context of a thesis work. Therefore, two students from the forth semester and of age 22 worked as a team. Basically, the students assumed the same procedure as those in Case Study 1.

5 EVALUATION

Both case studies have been evaluated in two ways: (1) by informal observations during the meetings and student works (Subsection 5.1) and (2) by a rather formal questionnaire that was done after the projects had been completed (Subsection 5.2).

5.1 Informal Observations

The participating students have shown significant achievements in various respects. Some examples are:

- The students have learned to work as a team and to organize the entire team work,
- They have developed quite a good understanding of the actual technical content, and were able to establish connections to previously learned fields,
- And for the team members, it was more than a natural behavior to help each other, they have experienced that a group, team-oriented performance is more than just the sum of the individual contributions.

5.2 Formal Evaluation

The Questionnaire. The formal evaluation was done by means of a questionnaire. This questionnaire contained open and closed questions. The questions addressed the following three main targets: (1) motivational aspects, (2) social and personal development, and (3) the acquisition and application of new content. This questionnaire was distributed close to the end of the project and evaluated the students' expectations they had at the beginning of the project as well as at the time of evaluation. These questions focused on the following two hypotheses: (1) does the model railroad project increase the students' motivation and (2) does this problem-based learning environment support the transfer of knowledge. The interested reader can download this questionnaire from the web (Salomon, 2009b).

The Teachers' Expectations. The students participated in these case studies with good grace and were highly motivated. The working atmosphere between the students and teachers was very good and was characterized by a very good discussion attitude. Therefore, the project leaders expected that the students highly sympathize with the two projects.

Motivation. The evaluation of the questionnaires showed – quite astonishing for the authors – that most students did not expect any positive effect the model railroad might have on their learning motivation. In addition, the students were not aware of any such effect by the time of evaluation. This rather surprising result might be interpreted as follows: the selected students were volunteers and

were thus anyhow interested in extra-curricular activities as well as in non-mainstream content.
But it might also be the case that these students were not fully aware of the motivational properties of the model railroad project on themselves: In several open questions, they indicated that they have participated in this project because they expected fun, can complement theoretical knowledge with practical experiences, and can realize their own ideas. Furthermore, the participating students anticipated an easy-to-handle and casual contact to the professor-in-charge. Finally, some participating students have indicated that they have chosen this project because they might be able to identify their own interests. In summary, the answers to those open questions suggest a high motivational spirit of this project.

Learning Effects. The students expected that at the end of the project, they can fuse theoretical knowledge and practical experiences. Even though the students did not expect a deeper *understanding* of the learned theories, they have apparently experienced a positive learning effect, since they have applied the theories during the design of the practical experiments. In other words, the model railroad learning environment has helped transform passive knowledge into active knowledge.

6 CONCLUSIONS AND OUTLOOK

This paper has discussed that tacit knowledge is present even in engineering disciplines, such as electrical engineering and computer science. As a possible relief, this paper has presented the model railroad project, as it is being developed at the University of Rostock. The main purpose of this project is to provide a problem-based learning environment to the faculty's students as well as engineering students in general.

This paper has also presented two case studies that have been carried out in the Summer Term 2009. These case studies have been done in the context of the model railroad project, and indeed indicate that the model railroad might be an appropriate approach for the avoidance of tacit knowledge.

In a survey, the participating students have testified that the model railroad has increased their motivation and that it has allowed to appreciate a self-regulated learning atmosphere. Furthermore, the evaluation has shown that the chosen learning environment supports some knowledge transfer.
Future research will be devoted to a more in-depth analysis of both causes and fulfillments of the students' expectations. In order to better appreciate the students' answers, future evaluations will be focusing on the identification of the students' individual learning concepts. In addition, future evaluations will also be considering relevant meta processes (especially individual learning, group and motivational processes), the effects of the model railroad has on knowledge application and structural deficits.

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REFERENCES

Coles, C.R. (1990). Evaluation the effects curricula have on student learning: Toward a more competent theory of medical education. In Nooman, Z.M., Schmidt, H.G., and Ezzat, E.S. (Eds.), *Innovation in medical education: An evaluation of its present status* (pp. 76-87), New York: Springer.

CTGV: Cognition and Technology Group at Vanderbilt (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher*, 19(6), 2-10.

Gräsel, C. and Mandl, H. (1999a). Problemorientiertes Lernen: Anwendbares Wissen fördern. *Personalführung: Für alle die Personalverantwortung tragen*, 32(6), 54-62.

Gräsel, C. and Mandl, H. (1999b). *Problemorientiertes Lernen in der Methodenausbildung des Pädagogikstudiums (Forschungsbericht Nr. 111).* München: Ludwig-Maximilians-Universität, Lehrstuhl für Empirische Pädagogik und Pädagogische Psychologie.

Gruber, H. and Mandl, H. and Renkl, A. (2000). Was lernen wir in der Schule und Hochschule: Träges Wissen? In: Mandl, H. and Gerstenmaier, J. (Eds.), *Die Kluft zwischen Wissen und Handeln. Empirische und theoretische Lösungsansätze.* (pp. 139-156). Göttingen, Bern, Toronto, Seattle: Hogrefe.

Gruber, H. and Renkl, A. (2000). Die Kluft zwischen Wissen und Handeln: Das Problem des trägen Wissens. In Neuweg G. H. (Ed.) *Wissen -Können - Reflexion.* (pp. 155-174). Innsbruck, Wien, München: Studien-Verlag.

Hmelo, C.E. (1998). Problem-based learning: Effects on the early acquisition of cognitive skill in medicine. *The Journal of the Learning Sciences,* 7(2), 173-208.

Kirschner, P.A., Sweller, J. and Clark, R.E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiental, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75-86.

Law, L.-C. (2000). Die Überwindung der Kluft zwischen Wissen und Handeln aus situativer Sicht. In: Mandl, H. and Gerstenmaier, J. (Eds.), *Die Kluft zwischen Wissen und Handeln. Empirische und theoretische Lösungsansätze.* (pp. 253-287). Göttingen, Bern, Toronto, Seattle: Hogrefe.

Mandl, H. and Friedrich, H. F. and Hron A. (1994). Psychologie des Wissenserwerbs. In Weidenmann, B. and Krapp, A. (Eds.), *Pädagogische Psychologie. Ein Lehrbuch* (pp. 143-218). Weinheim: Beltz.

Moore-West, M., Harrington, D.L., Mennin, S.P., Kaufman, A., and Skipper, B.J. (1989). Distress in attitudes toward the learning environment: Effects of a curriculum innovation. *Teaching and Learning in Medicine*, 1(2), 151-157.

Newble, D.I. and Clarke, R.M. (1986). The approaches to learning of students in traditional an in an innovative problem-based medical school. *Medical Education*, 2, 267-273.

NMRA (National Model Railroad Association) (2007). *DCC Homepage.* Retrieved November 26, 2009, from http://www.nmra.org/standards/DCC/index.html

Salomon, R. (2009a). *Modellbahn Studentenprojekt.* Website. Retrieved November 26, 2009, from http://modellbahn.uni-rostock.de/index.php?id=team

Salomon, R. (2009b): *Questionnaire.* Retrieved December 9, 2009, from http://www.imd.uni-rostock.de/ma/rs/conf/questionnaire-12-09.pdf

Strobel, J. and Barneveld, A. v. (2009). When is PBL more Effective? A meta-synthetis of meta-analyses comparing PBL to conventional classrooms. *The Interdisciplinary Journal of Problem-based Learning,* 3(1), 44-58.

Vernon, D. T. and Blake, R. L. (1993) Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine*, 68, 550-563.

Zumbach, J. (2003). *PBL Problembasiertes Lernen.* Münster: Waxmann.