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Vocational Education and Training

Leading House

DUAL-T: Technologies for Vocational Training

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(Signature)

This report is delivered before the end of the second year of activities in order to respect the following agenda: our advisory board would evaluate it and provide feedback to the scientific steering committee for its meeting of April 18th.

Contents

1.	DEVELOPMENT OF THE LEADING HOUSE	4
1.1.	Scope	4
1.2.	Situation	4
1.3.	Collaboration between projects	5
1.4.	Launching of project 4	6
1.5.	Perspective for year 3	6
2.	PROJECT 1 (FRIBOURG)	7
2.1.	Context	7
2.2.	Conjectures map	7
2.3.	Study 1: The analysis of help-requests	8
2.4.	Study 2: Comparing help-seeking school and workplace.	10
2.5.	Workplan for year 3	11
3.	PROJECT 2 (GENÈVE)	12
3.1.	Context	12
3.2.	Conjectures map	12
3.3.	Study 1: Attitudes towards vocational training	14
3.4.	Study 2: Writing about work experience	15
3.5.	Study 3: Repeated writing activities	16
3.6.	Study 4: Writing about procedures	17
3.7.	Study 5: Writing from experience	18
3.8.	Workplan for year 3	20
4.	PROJECT 3 (EPFL)	21
4.1.	Context	21
4.2.	Conjecture map	22
4.3.	Main Study	23
4.4.	Work plan for year 3	30
5.	TRAINING YOUNG RESEARCHERS SCIENTISTS	31
6.	OVERVIEW OF YEAR 2 ACTIVITIES	31
7.	PUBLICATIONS	32
8.	BIBLIOGRAPHY	32
9.	APPENDIX 1 : TYPOLOGY OF HELP REQUESTS	35

Overview of DUAL – T

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Pierre Dillenbourg and Florence Colomb coordinate the leading house activities.

1. Development of the leading house

1.1. Scope

The potential of learning technologies in vocational training goes beyond traditional e-learning approaches (documents, exercises,...). DUAL-T explores learning activities that are relevant to the dual world, i.e. which stretch over schools and workplaces. The first year of research enabled us to identify specific needs of dual training that could benefit from technology enhanced learning. We encountered multiple instances of what we called the "skills gap", that is situations where the apprentices do not have the opportunity to practice at their workplace the skills that have been defined as objectives by the vocational training system. We met car mechanics apprentices who spend most of their time changing tires instead of repairing engines. We met dental assistants whose activity is restricted to cleaning tools instead of applying the procedures taught at school. We met future logisticians who have no opportunity for reasoning on their workplace logistics since they only have to move boxes between two locations chosen by a computer. Fortunately, while some workplaces do not provide opportunities for training these skills, other workplaces do it very well. Through technologies, apprentices may mutualise the experience gained across the latter and the former (project 2); they may practice in simulated worlds the skills that are not activated in their workplace (project 3) and they may access at their workplace some resources provided at school. Therefore, *DUAL-T considers technologies as "bridges" over the skills gap*. The effectiveness of learning technologies will depend on the extent to which they support activities that target key cognitive skills (self-regulation, reflection and abstraction) without disconnecting these skills from the professional context.

1.2. Situation

The initial *observation phase* of our 3 research projects concerned the life of apprentices both at workplace and at school, but with a special focus on what they do and learn at the workplace. In this second year, we moved into an *intervention phase*: we designed learning activities as well as the technology necessary to conduct these activities. These activities are mostly designed for schools where intervention studies are more tractable. In a classroom, we easily can reach 20 apprentices within a single experiment as opposed to negotiating with the 20 companies where they are working. Doing experiments in schools nonetheless requires building a partnership with the schools, not only with the management but with all the involved teachers as well.

The involvement of teachers is a key dimension of our *integrated learning* framework (Dillenbourg & Jermann; 2007): as described in our first year report, technologies are not designed as stand alone learning tools but for supporting pedagogical *scenarios* that include individual activities (reading, writing, summarizing,...), group activities (solving problems, arguing,...) and class activities (debriefing, synthesis, introductory lectures,...). In these scenarios, the teacher is orchestrating the physical and cognitive aspects of these activities. Doing research along these lines requires a *partnership with teachers in order to co-develop scenarios* that target relevant pedagogical objectives, satisfy numerous practical constraints and address our research questions.

Our research proposal specified that we will adopt *design based research* (DBR) as methodology. We follow the approach outlined by The Design-Based Research Collective (2003) which consists in testing and building working theories to make sense of a field of investigation through an iterative design and intervention cycle. The partners of this leading house are more familiar with formal experiments and quantitative methods, but, given the novelty of this approach and context, it made more sense to follow the iterative refinement process of DBR than to a priori choose some independent variables.

According to Wang and Hannafin (2005), the key points of DBR are 1) it aims at refining both theory and practice 2) through interventions which are grounded in theories and take place in real-world settings 3) with an active participation of the participants in the design 4) through iterative cycles of analysis, design, implementation and redesign 5) by the use of an array of methods from field observations to controlled surveys 6) leading to results which are articulated to the specific context of the studies.

Given the importance of DBR for our projects, we organized a workshop on these methods and invited Prof. William Sandoval (UCLA), who is a member of The Design-Based Research Collective. The key issue we addressed is whether DBR methods, besides producing well-adapted learning tools through iterative design, do also enable generalization of results in order to produce new scientific knowledge. The DBR way to reach this generalization is to articulate objectives, design choices and results within what they refer to as "conjecture maps". According to Sandoval (2004), "designed learning environments embody conjectures about learning and instruction, and the empirical study of learning environments allows such conjectures to be refined over time" (p. 213). He discriminates theoretical conjectures that correspond to research hypotheses in a more formal framework, from "embodied" conjectures, which are the ways the theoretical conjectures are reified in a "designed" learning environment. The "designed" environment does not only refer to a piece of technology but also to the learning activities and related activity structures (Erickson, 1982). This vision fits perfectly with our "integrated learning" framework. The embodied conjectures predict outcomes at two levels: (1) intermediate outcomes are observable patterns of behaviour predicted by a model of how an embodied conjecture functions should support learning. (2) intervention outcomes finally refers to whether students learn what they are intended to learn. In summary, a conjecture map links theory elements to design elements, relates design elements to intermediate variables and finally to desired outcomes. Each link embeds a hypothesis to be supported by empirical data. We decided to use these conjecture maps in this report as they convey an overview of our investigations. Each project includes a conjecture map inspired by the 4 basic elements presented in table 1.

Table 1: Elements of a conjectures map

Theoretical conjectures	Embodied conjectures	Intermediate outcomes	Objective outcomes
Theoretical line, hypotheses and expectations	Design elements that turn theory principles into concrete features	Actions and interactions that actually occur during the activities	What students actually learn.

1.3. Collaboration between projects

DUAL-T partners share a vision of learning technologies that has been described in the first annual report, the "integrated learning" approach. A clear and shared vision constitutes an important strength to impact on the Swiss vocational training landscape. The internal consistence of the leading house was further strengthened by the findings of our observations which, despite many differences among the professional contexts we explored, converged towards the notion "skills gap", explained here above. This convergence probably results from the regular meetings gathering all leading house actors (PhD students and scholars). The members of our advisory board have however suggested that the partners could share not only their theories and their empirical findings but also the tools they have developed. While the technology of project 3 is very specific, they stressed that the ELGG environment tailored by project 2 could actually enrich the learning activities in project 1 (to move from the observation mode to an intervention mode) as well as in project 3 (sharing warehouse configurations and simulation logs as well as sustaining reflection on warehouse experiments).

1.4. Launching of project 4

At the end of our first annual workshop, the advisory board suggested that the best contribution of a fourth project would be to expand the experiments conducted by the 3 initial partners. A call for proposals has been issued in summer 2007. Only one application has been received. It has been approved by the leading house, its advisory board and the programme steering committee. The applicant is the Swiss Federal Institute for Vocational Training (SFIVET). Their aim to generalize DUAL-T technology-enhanced learning activities across professional contexts and across cultural (linguistic) contexts. The target professional contexts have been negotiated through successive meetings. Project 4 is orthogonal to the 3 other projects and hence constitutes an overarching roof for the leading house, strengthening the coherence of DUAL-T.

SFIVET is a particularly well suited for this mission as they interact with vocational training schools and companies as well as corporate associations all over Switzerland. Their actual work will start at the third year of this project but they have already started to interact with the 3 other partners since the creation of the leading house. Namely, four SFIVET members have attended our annual workshops and have already influenced the work in DUAL-T. Several additional meetings have been organized to refine the details of our partnership.

At the end of our second annual workshop (February 2008), the members of our advisory board have suggested revisions of the project 4 work plan. They argued that the 3 initial projects had different degrees of generalisability which should be reflected in the workplan of project 4. For instance, as project 3 is bound to specific contents to be taught, the advisory board suggested that scaling up the approach to multiple schools in the same vocational context would already be a significant accomplishment compared to most projects in this field. Hence, the details of the empirical studies to be conducted by project 4 are still under negotiation.

1.5. Perspective for year 3

In 2007, the leading house has reached its cruise speed and has been multiplying empirical studies. From the academic viewpoint, the number of publications and oral communications about the leading house is rising. The large amount of empirical data collected over the last months constitutes a valuable asset for targeting high quality educational journals in the near future. Moreover, the leading house will produce several PhD theses in the field in the coming years. From the applied viewpoint, we have strengthened our partnership with schools and companies involved in the respective projects. For instance, we will soon have an official inauguration of the environment installed in the Centre Professionnel du Nord Vaudois (Yverdon).

The programme for year 3 is described for each project of this document. In addition, we intend to organize a national/international conference in 2009, probably in collaboration with the conference that SFIVET intends to organize. The management of the leading house requires to have a *perspective on the future beyond year 3*. If this leading house will stop at the end of the 3 year long contract, priority will be given to completing on-going experiments and exploiting the results. If the leading house is expected to last longer, more energy will be devoted for gathering partners across the country (universities, applied sciences universities, vocational training schools, etc.). **We hope to get some clarification of the time horizon of the DUAL-T leading house by the summer 2008.** We have already started to bring in Swiss colleagues interested by vocational training, such as Prof. Laurent Fillietaz (University of Geneva) who has been invited to our second annual workshop. Our workshop on design-based research has also been open to colleagues from Switzerland.

2. Project 1 (Fribourg) : Fostering autonomy through on-line scaffolds across learning contexts

2.1. Context

The target population of this project is car mechanics apprentices. The project is based on the conjecture that one of the major achievements of learning a profession is *to become autonomous* in performing the tasks which are central to that profession. Autonomous learning differs from simple "trials and errors" learning by stressing the importance of understanding what one knows and doesn't know and finding the information and support needed for improving one's skills and knowledge. Mobile communication technologies, we hypothesize, should increase the possibilities to acquire such information and to share experience beyond one's proximal surroundings.

2.2. Conjectures map

In this second year, we have extended study 1 and developed study 2. Since the theoretical background of study 1 has been presented last year, we now describe the theoretical framework of study 2, expressed as a conjecture map. Study 2 is rooted in the theory of help-seeking (figure 1). This literature explored three directions: (a) to recognize types of students' help requests, (b) to understand the reasons why some students do while others don't ask for help when they need it and (c) to examine which features of the social environment encourage or hinder help seeking. Two hypotheses explain reluctance in seeking help: metacognitive (insufficient awareness of help needs) and socio-cognitive (avoidance of asking help in order not to look stupid or incompetent) r

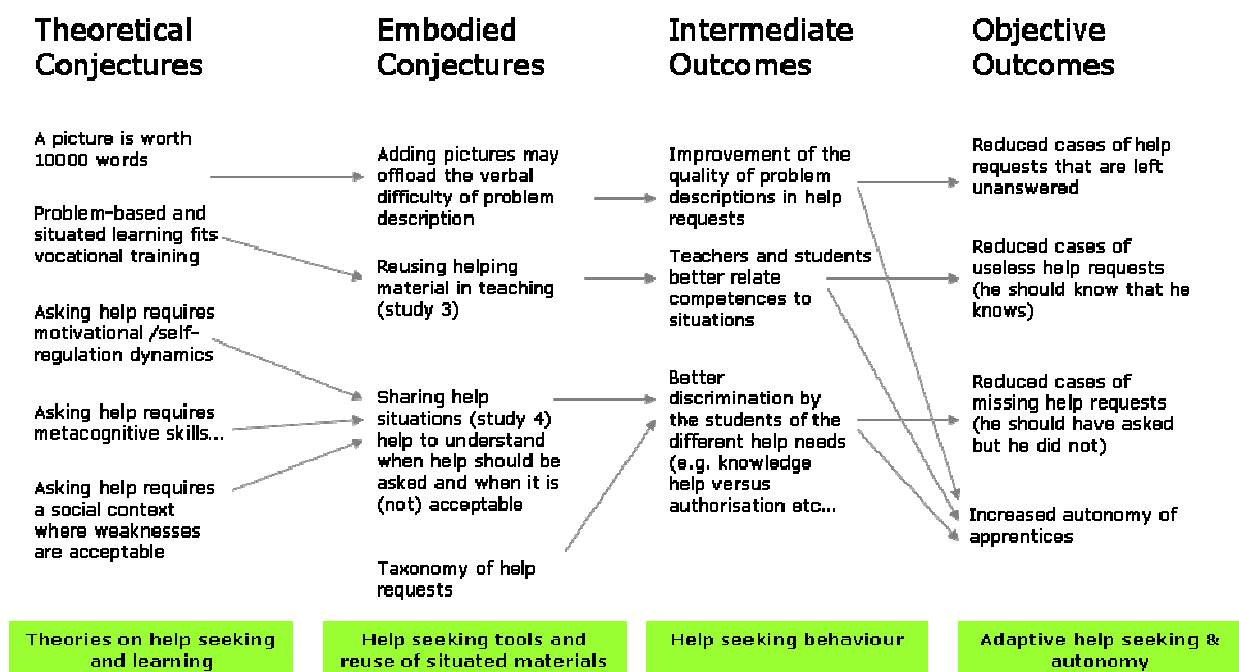


Figure 1. Conjectures map for study 2.

The vast majority of studies on help seeking have however been conducted in academic school contexts. If not asking for help when needed at school only has limited immediate effect at school, the consequences of not having asked for help when needed at the workplace may well be much more disastrous. What will be the effect of this discrepancy

on apprentices of the dual system, who live part time at school and part time at the workplace in two different organizational cultures. Understanding the specificity of such contextual effects on help-seeking, we hope, should allow us ultimately to influence teachers and supervisors attitudes and openness towards the questions and help requests which apprentices could or would like to ask them.

2.3. Study 1: The analysis of help-requests

Research questions. Our main question is: Could the apprentice's questions and needs for help at the workplace be answered "at distance" ? More specifically, we are currently dealing with the following three sub-questions:

- What type of problems does an apprentice face at the workplace and what kind of help-requests does he formulate? What is the frequency of each type of question or help-request?
- To whom are these help requests addressed?
- Do these help requests require a physical meeting or could they be formulated and answered « at distance »?

Methods. Study 1 is a technology assisted ethnographical study of apprentices at their workplace. Participants were apprentices in car mechanics (year 1 through 4). Over two to four weeks, they were asked to turn on their cellular phone while working at the garage and to wear headsets and a microphone. We called them regularly for approximately one hour. During this call, they were asked to verbalize what they were doing. The study did not target specific tasks. Each of these phone conversations has been recorded and transcribed. Our analyses focus on critical episodes, i.e. the moments when apprentices require some form of help from somebody else in the garage. Thirteen apprentices and 60 conversations have been transcribed and analyzed.

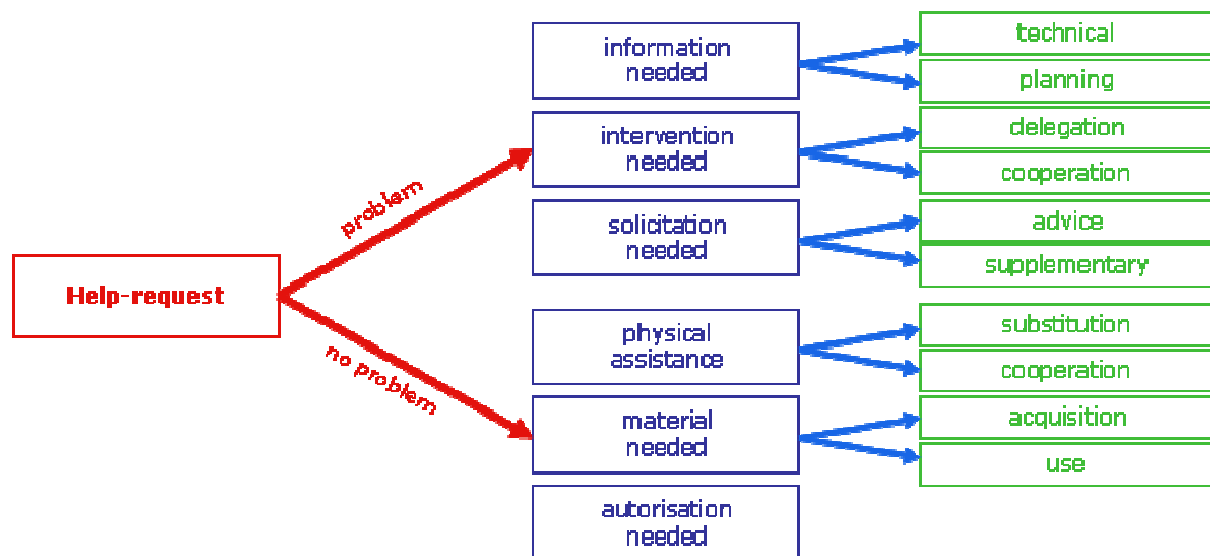


Figure 2. Typology of help-requests by apprentices (categories are listed in appendix 1.)

Results. The analysis of recorded conversations led us to define a typology of the problems and questions expressed by apprentices. This typology distinguishes between 11 categories of help requests (see Figure 2). Table 2 provides the details. Among the 475 requests, 45% were requests for information (planning and technical information), 22.2 % were requests for an advice or similar solicitations. Only 3.6% of the requests

were clearly asking a more able person in the garage to take over the responsibility of the apprentice's job (intervention).

Table 2: Frequency of different help-requests

Type of request	Number	%
Technical information needed	113	24
Planning information needed	102	21
Intervention delegation needed	7	1.5
Intervention cooperation needed	10	2.1
Solicitation needed: advice	56	11.8
Solicitation needed: supplementary	49	10.4
Physical help-substitution needed	4	0.9
Physical help-cooperation needed	24	5
Material: acquisition	43	9
Material: use	55	11
Authorization	12	2.6
Total	475	100

Interestingly, advanced apprentices (third or fourth year) tend to require help or ask questions more often than younger apprentices, as illustrated in figure 3. The explanation is probably less related to better metacognitive skills than to the increasing complexity of tasks and the degree of responsibility assigned to older apprentices.

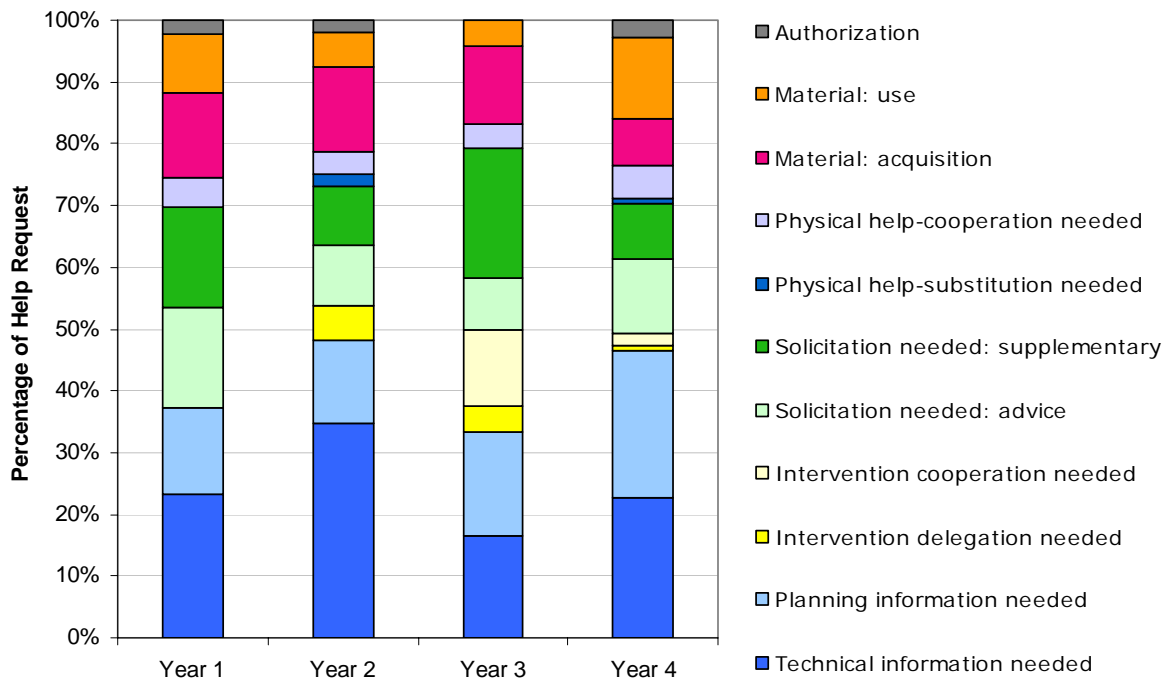


Figure 3. Type of help requests across training years

Two thirds of the requests resulted in a physical move from the apprentice towards the « helper » and conversely the helper physically moved towards the apprentice in 40% of the cases. In rather large garages, such as the ones we worked in, the help-requests were addressed to a broad range of persons with different status and functions within the garage. We are currently investigating the relationship between the types of request,

the addressee and what we call the « opportunity », i.e. the accidental proximity or absence at the very moment when help is needed as well as his degree of experience.

Discussion. Globally, help requests and questions are common while training at the workplace. In rather large garages, opportunities to ask for help are important with co-workers and fellow apprentices, but less frequent with the supervisor. Communication technology could serve here to enlarge connecting opportunities with supervisor.

2.4. Study 2: Comparing help-seeking at school and at the workplace.

Most studies dealing with learners' attitudes towards help-seeking have been conducted in academic settings while apprentices in the dual system are only a short period of time at school and spend indeed most of their training time in an enterprise.

Questions. In this second study we address the following research questions:

- What are apprentices' attitudes towards help-seeking, compared to those described in the literature for academic contexts?
- Are apprentice' help-seeking attitudes and behaviors at the workplace the same as at school? The underlying question is whether attitudes towards help seeking are more personality dependent and therefore rather similar over the two contexts or more context-dependent.
- Will professions (mechanics, wood, precision mechanics or construction) or school year (1st to 4th year of training) modify attitudes towards help and help-seeking?

Our hypotheses are that:

- Apprentices would see help seeking as more fruitful at the workplace than at school.
- Avoidance to ask for help should be lower at the enterprise than at school.
- Living in the two contexts for a longer time should reduce the difference between the respective attitudes towards seeking help in the two contexts.

Methods. As usual in research dealing with attitudes, our hypothesis have been evaluated by using a questionnaire. Within the literature on help-seeking, many dimensions have been distinguished. For the purpose of the present study, we kept 11 dimensions. Every item explicitly referred once to the school context and once to the workplace context. The questionnaire includes 46 items for which participants had to indicate their degree of agreement. Examples of items are "At school if I need help, I ask my colleagues to give me hints or clues rather than the answer" (*item 8*). "At the workplace, if I need help, I ask other workers to give me hints or clues rather than to accomplish the task for me" (*item 31*). Altogether, 160 apprentices from two different vocational schools in Switzerland answered the questionnaire.

Results. We found significant differences between the two contexts for most of the questionnaire's dimensions:

- Apprentices consider that they are more likely to ask for help spontaneously to anyone at the workplace than at school ($t=5,414$, $dl=159$, $p=0,000$).
- Apprentices declare getting help from a formal source as more important at the workplace than at school ($t=3,738$, $dl=159$, $p=0,000$). Apprentices judge more important to ask for hints in order to accomplish a task (adaptive help-seeking) at the workplace than at school ($t=3,840$, $dl=154$, $p=0,000$).
- Considering help as a way to improve the quality of the work to be done is more frequent at the workplace than at school ($t=3,902$, $dl=157$, $p=0,000$). However,

apprentices refrain from asking help to avoid looking incompetent (Help-seeking avoidance) at the workplace more often than at school ($t=7,049$, $df=158$, $p=0,000$).

- Apprentices prefer to ask help directly from the "authority" (teachers or supervisors) rather than from a fellow apprentice. This result is sharper at the workplace than at school ($t=3,586$, $df=157$, $p=0,000$). Conversely, "getting help from an informal source", i.e. from fellow students or another apprentice, is higher at school than at the workplace ($t= -2,195$, $df=157$, $p=0,030$).

The school year, according to an ANOVA multivariate analysis, yielded only some significant effects: along the years, apprentices do more informal help-seeking at school ($F_{(3,147)}=2,990$, $p<.05$) and, conversely, more adaptive ($F_{(3,147)}=4,774$, $p<.05$) and more formal help-seeking ($F_{(3,147)}=5,041$, $p<.05$) at the workplace. Means analyses show that, at the workplace, informal help is progressively replaced by formal help over the years of training. Conversely, "avoidance of seeking help due to a fear to look stupid" decreases over training in both contexts. The differences in attitudes towards help across contexts do not evolve consistently over the years of training, although they tend to be smaller in the last year of training, than at any other time.

Discussion. The results indicate that contexts play an important role in apprentices' attitudes towards help-seeking. Hypothesis 1 is confirmed: apprentices are more positive towards help-seeking at the workplace than at school and they see help as more useful there than at school. Neither the second nor the third hypotheses could be confirmed. Avoidance to ask for help in order not to look stupid or incompetent is higher at the workplace than at school. Even if last year of training's differences in attitudes across context happen to be smaller than the differences noticed in the first two years of training, no clear pattern of evolution could be noticed over all the 4 years.

2.5. Work plan for year 3

As suggested in February by the advisory board of the leading house, this project will move from an observation/analysis stance towards an intervention approach. The third year of the research will focus on pushing apprentices to share with their peers the experience gained at the workplace. This approach will be conducted in two ways:

- Study 3 will examine how teachers can make use at school of particularly interesting critical episodes observed in Study 1. Pedagogical scenarios and material is currently under construction together with a team of professors from different vocational schools and will serve as the basis for the curriculum in "problem solving and interpersonal skills" to be next introduced in all Swiss vocational schools. The four French speaking canton and the professional association have decided to integrate this material in their curriculum.
- Study 4 will ask apprentices to use their mobile phones to capture interesting problematic situations they happen to face at the workplace and to share them with fellow apprentices and their teachers at school. We currently examine the possibility to reuse the ELGG platform set up by Project 2. Collective reflections will then be initiated at school around these problematic situations and their significance as learning prompts will be discussed. Sharing will not only give opportunities to put words on problematic situations, it should also broaden the scope of situations which apprentices will have a chance to be confronted with during their training. Due to the high reliability of modern cars, procedures to be executed during practice in the garages nowadays tend to be more and more repetitive, less and less creative.

3. Project 2 (Genève) : Computer-supported collaborative writing in vocational training

3.1. Context

Project 2 focuses on apprentices in the health sector and particularly on dental care assistants. It investigates how ICT can support learning activities involving writing and reflecting about apprentices' professional experience in the workplace. During the first year, this training context was analyzed through class observations, as well as interviews with students and teachers. Outcomes were data regarding students' attitudes towards school activities and towards the profession. In addition, we conducted observations in dentist cabinets in order to get information about a dental assistant's actual activity. We then investigated second year apprentices' attitude towards writing by using two scales: the "Writing Apprehension Scale" (Daly & Miler, 1975) and the "Writing With a Computer Scale" (Shaver, 1990). Results from this survey showed a low level of apprehension, which reinforced the initial idea to use writing activities. We also conducted a preliminary learning activity using an initial version of the community platform ELGG. Apprentices successfully completed the tasks, but we had to make some adjustments to the platform in order to overcome some limitations students or teacher encountered.

Platform. In March 2007, after long negotiations with the authorities in charge of ICT in Geneva schools (Centre of the Technologies de l'Information; Service Ecole Media), we brought ten laptops and a Wi-Fi network into the dental care assistants school. PCs were installed with a collection of basic office software, are updated regularly and are currently in use in the classroom. After an inventory of existing collective writing tools made, we selected the ELGG software platform (www.elgg.org). ELGG can be described as *Social Networking Content Management System* that is based around content, individuals, communities, communication and documents. Users can incorporate various contents in different ways within one environment and share specific information with other people. ELGG integrates with other environments, e.g. through RSS-feeds or user authentication with OpenID. ELGG was specifically developed for educational needs, i.e. as an attempt to create an infrastructure for so-called e-learning/school "2.0" pedagogies. ELGG has a growing user and developer base and new releases with new functionalities are frequent. The pedagogical scenarios we developed with the schoolteachers integrate this platform and in particular, its ePortfolio and social network functionalities. We also integrated the MediaWiki software into ELGG and we developed extra extensions such as a PDF export functionality for created e-portfolios or a global overview of user-activities.

3.2. Conjectures map

In agreement with the leading house framework, the next phase of the project aimed at implementing computer-supported activities promoting three learning objectives:

- **Articulation:** in order to help apprentices make links between learning at school and practice at the workplace, we designed school activities involving writing about practical experience from the workplace;
- **Reflection:** in order to promote reflection on complex subject matters in relation with practice, we use collaborative writing activities such as peer commenting and collaborative construction of a common knowledge base;
- **Identity:** collaborative writing activities promoting experience sharing, like building a common knowledge base and comparing experiences varying across workplaces, should foster the construction of a strong and positive professional identity.

We formulated two main research questions relative to the three learning objectives described above.

- First, *can collaborative writing activities promote the acquisition of procedures?* Focusing on procedures is particularly relevant in dentist assistants' training, since the assistant should not only know the treatments' sequence of steps, but also anticipate what to do in case of troubles in order to assist adequately (i.e., prepare instruments and products). Acquisition of procedures is thus defined as the comprehension of the "whys" beyond the "how to".
- The second question is more oriented towards the design of a relevant learning framework (Dillenbourg & Jermann, 2007). *How should the computer-supported learning environment be designed in order to improve subjective and objective learning of procedures?* By design we not only mean the type of activities (here collaborative writing activities) but also practical design issues, such as the features and interface of the computer environment and the scenarization (scripting) of the learning activity.

The computer environment should be designed in a way that supports such activities and that enables the underlying processes: writing, storage, linking, revision, history tracking, commentaries and discussion.

An overall conjectures map including the major theory, design, process and outcome elements of the studies planned in this sub-project is reproduced in Figure 4.

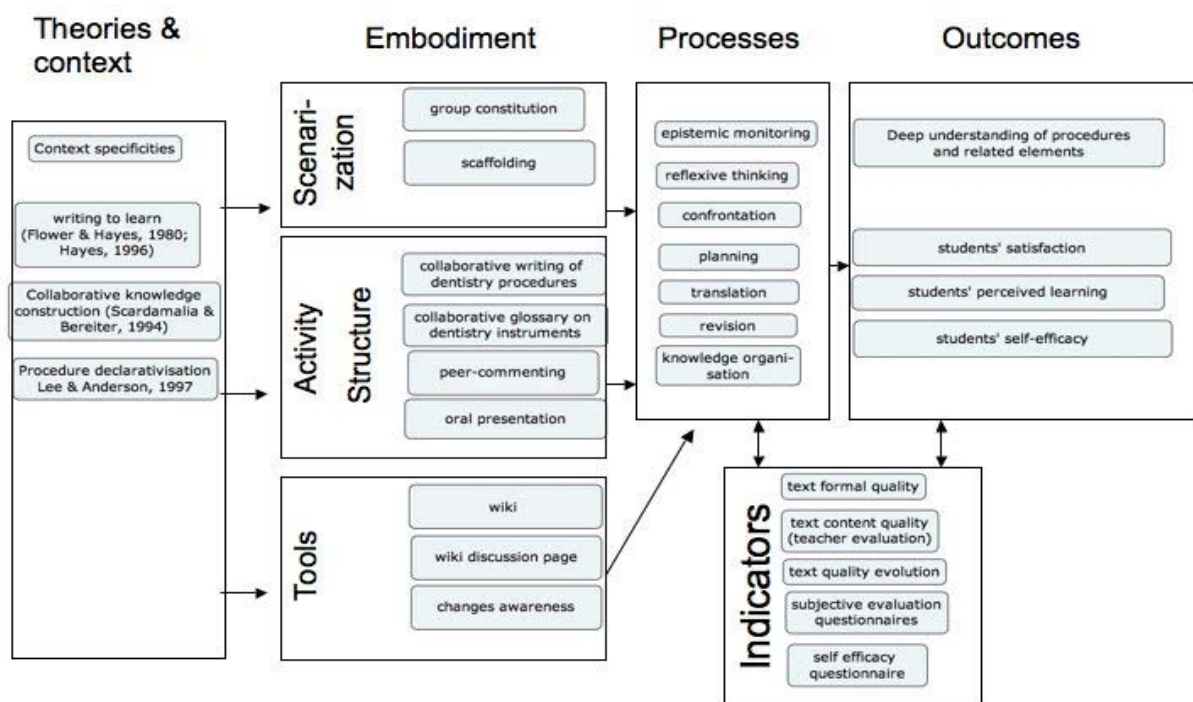


Figure 4: Overall conjecture map of project 2

On the left-hand side of the conjecture map, we identified the theories and context on which our hypotheses are based. First, the "writing-to-learn" model (Flower and Hayes, 1980; Hayes, 1996) assumes that writing promotes the acquisition of knowledge through three iterative processes: *planning*, *translation* and *revision*. According to this cognitive view of writing-to-learn, knowledge transformation leads to knowledge constitution (Galbraith, 1999). Furthermore, according to Lee & Anderson (1997), the

acquisition of procedures requires a first “declarativisation step” during which the learner should explicitly describe the sequence of actions to be performed and related relative considerations (pre-conditions, consequences). A writing activity should then be expected to support the elaboration of declarative statements about the procedure, as shown by Catrambone & Yuasa (2007) with self-generated explanations. The second model, collaborative knowledge construction, emphasizes the benefits of having learners interact on their productions in order to provoke various meta-cognitive mechanisms beneficial to learning, and particularly conceptual change and deeper understanding.

Regarding the embodiment dimension, we distinguished the structure of the activity, pedagogical scripting issues and computer tools. Such design elements should provoke some specific cognitive processes beneficial for learning. We will develop and test two kinds of collaborative writing activities implementing these design elements: peer-commenting and collaborative knowledge construction.

- The “peer-commenting” writing scenario consists in assisting the revision process through the intervention of a peer, following the peer-tutoring assumption. Peer-tutoring is expected to enrich the production through the *confrontation* with other learners, and by fostering metacognitive awareness on their own productions, particularly *epistemic monitoring* and *reflexive thinking*.
- The second activity, “knowledge building”, refers to scenarios that lead to the progressive and *collaborative construction* of a common knowledge base, following Scardamalia and Bereiter’s assumption (Scardamalia & Bereiter, 1994). From a cognitive point of view, this activity is expected to promote ideas *confrontation* and conflict resolution. Moreover, as the activity leads to a common knowledge base from various work experiences, it should foster the feeling of belonging and professional identity. Note that the box “context specificities” refers to the knowledge acquired on the field through thorough investigations and through the participation of teachers in co-designing learning activities.

In study 5, the activity was the description of a procedure (root canal treatment) and the constitution of a database of the instruments that are used in this procedure, with a group phase and an oral presentation to the class. The tool we selected tool is a wiki, which supports for reification of knowledge and process through features such as history, commentary page and collaborative edition.

In study 6, peer-commenting will be used as the collaborative writing activity, which involves three phases: individual production, crossed peer-commenting and revision of the initial entry. The main pedagogical issue is to scaffold focused commentaries. The tool allows for revision of individual entry and commentary. A journal or blog tool will be adequate to support peer-commenting if the scenario is repeated over several sessions.

Success of activities (outcomes) will be evaluated through objective and subjective learning outcomes. The objective learning outcomes will be mostly evaluated through the quality of the text produced (and the comments), measured using formal indicators and the teacher’s evaluation of content accuracy. Pre / post-test comparisons will be used in the long-term studies (study 7). Subjective learning outcomes will be measured with questionnaires (satisfaction, enjoyment, effectiveness, self-efficacy).

3.3. Study 1: Attitudes towards vocational training

Goals. In agreement with the design based research approach and in order to know better the population, we investigated apprentices’ training background and experience, their attitude towards the training at school and apprenticeship in the workplace, and their use and attitude towards ICT (personal, professional and learning uses).

Methods. We conducted semi-structured interviews with a sample of 10 second-year apprentices. Based on these interviews, we then constructed and administered a survey questionnaire to the whole second year population.

Results. The semi-structured interviews and the follow-up questionnaire revealed a rather heterogeneous population. Apprentices differ with regard to prior training (e.g. some started another apprenticeship before) and to career plans. Work tasks and tutoring support vary widely across dental practices. Accordingly, self-estimated skill levels differ largely across apprentices. Most apprentices have access to a computer at home, but only about half at work, even though there is always at least one computer at the workplace. Structural equation modelling (SEM) analyses of survey's results showed three salient results.

1. It seems that the apprentices' declared mastery of skills depends on the size of the practice they are working in and their preference for branch courses: the bigger the size of the cabinet, the lesser their estimated mastery of professional skills. Surprisingly, apprentices who claim mastering skills very well say they don't appreciate the branch courses. This might be because well-trained apprentices may find the course redundant. Also, self-estimation of mastery is not related to liking the whole training.
2. SEM analyses also revealed the factors that seem to determine the apprentices' attitude towards the computer: having full access to a computer at home, having internet access at home and the weekly spare time spent on a computer.
3. We identified some of the predictors of the apprentices liking of this vocational training. It seems that their future plans have a great influence as well as their "punctuality" in doing the homework, together with the preference for the branch courses (the ones related to dentistry) and the English course and dislike of the general culture course. This last factor is coherent with the other ones since the general culture course is the less linked to professional issues.

Results of these investigations suggest that computer supported writing activities about one's work experience are feasible with dental care apprentices, although not necessarily in the workplace. The large heterogeneity we discovered in the students' profiles could be a very good basis for collaborative knowledge building writing activities. The large differences observed in the quality of workplace training can be put to advantage in collaborative designs within which apprentices learn from the skills and knowledge of their colleagues and enrich their knowledge by sharing it with the others.

3.4. Study 2: Writing about work experience

Goals. The goal of this first computer-supported learning activity was to (1) introduce computer supported writing application to teachers and apprentices, (2) to observe the reactions of the participants in order to obtain useful information to improve further computer-supported collaborative writing activities and the computer environment.

Method. The activity was co-designed with an ICT teacher of the dental assistant school. The 23 second year apprentices were asked to report on a difficult, problematic situation they experienced at work, in the dentist practice. They then were instructed to comment on one colleague's entry. This activity was a part of an actual class. In order to complete the task, the apprentices used the laptops that we provided to the school. The activity took place on the ELGG platform using the Blog functionality.

Results. Most students quickly learnt how to make entries and comments; they all were able to complete the task. They were not reluctant to write about their experience. Quantitative analysis of the writing productions revealed a great heterogeneity in the length of the produced text, especially for the comments. For the 15 minutes dedicated

to problem telling, the 23 apprentices wrote a sum of 862 words, i.e. a mean of 37.4 words per student (min=11, max=92, SD=18.9). This result is satisfactory for a trial and familiarisation activity with the platform. For the 10 minutes dedicated to commenting the peers' entry, the apprentices produced 852 words with a mean of 37 words per student (min=0, max=196, SD=36.2). Five apprentices did not produce any comment. Those results show that this type of writing activity is feasible with apprentices. The large heterogeneity found in the commenting activity could be explained by three factors: (i) students had to perform rather technical actions in order to find the peer's entry, read it and post a comment; (ii) this activity may be more cognitively complex; (iii) students might not have understood the importance of the commenting activity and therefore did not grant enough importance to this part of the activity.

Qualitative analysis revealed large differences in the quality of the writings and enabled a first classification of the problems dental care apprentices face during their work practice and that we may integrate in further scenarios. We identified five categories of problems. The apprentices mostly reported difficulties regarding work organisation and interpersonal relations with the colleagues. Difficulties regarding skills and knowledge came second.

At the end of the activity, we did an interview with the IT teacher in order to have her opinion on the platform and the exercise. She focused on usability problems of the platform, but also showed optimism regarding the platform's utility for supporting the course and knowledge building activities. The teacher showed us the problems she encountered using the different functionalities of the platform. She had difficulty to identify where she was in the platform (a hierarchic hint). She found the list of the menus not very coherent, some menus are redundant and specific operations were difficult to be accomplished (too many clicks needed). She then formulated the need for printable page versions of the platform content. Finally, she expressed the wish that learner should be able to re-edit the blog entries and have access to the editing history.

Discussion. Following the analysis of the first study's results and the interview with the teacher, some modifications were brought to the ELGG platform. We added new functionalities such as the possibility to view the combined blogs entries in chronological order, to print individual blog entries and the possibility to export student's productions as a single PDF file for reading after class. These additions improve portfolio functionality. Since the built-in blogs do not support editing history or collaborative writing activities with a same text, we also interfaced ELGG with a MediaWiki system, which we introduced in the second study reported below.

3.5. Study 3: Repeated writing activities

Goal. The goal of this study was to analyse the feasibility of a "longer term" utilisation of the platform. In addition, we wanted to continue the process of familiarisation with the electronic environment in the school.

Method. The activity was co-designed with the English teacher of the dental assistant school. Two weeks in a row, students were asked to follow the traditional course and then, at the end of the lesson, they were given 10 minutes to enter in the platform's blog some notes on information received in the course. They had to answer the question "what did I learn today" in the most structured and organised way they could. The third week, the teacher asked them to write a letter on ELGG, using the information learned in the previous two classes. They had quick access to this information on the platform, since they had synthesised it in the previous two classes.

Results. First, we could notice a good contact of the apprentices with the platform. They had only seen and used it once before but they showed a good mastery and a positive attitude. For the teacher, this was the first contact with the platform. Even though in the

beginning he was reserved and afraid to commit mistakes, at the time of the third intervention, he was using the tool with much more comfort, confidence and pleasure.

The analysis of the apprentices' three consecutive entries showed a progression in the quality and length of the texts as well as a good quality in the final production. In figure 5, we refer to high quality for well organized, complete and/or relevant texts, and medium for good texts but not complete or grammatically incorrect.

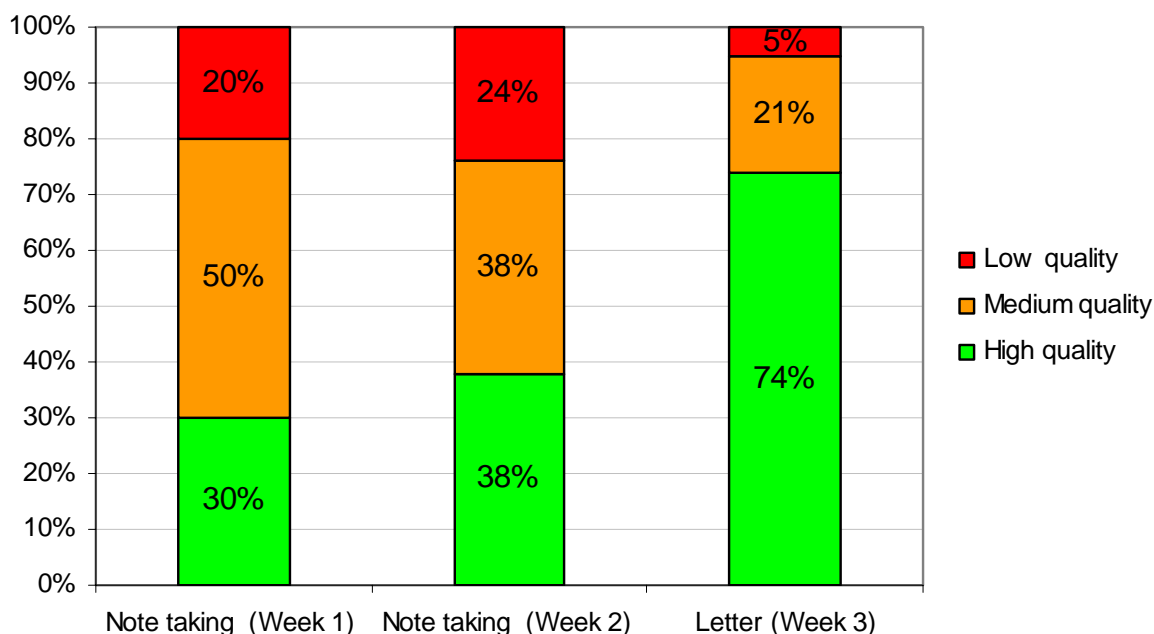


Figure 5: Evolution of the quality of students' text productions

Discussion: This study allowed us to confirm the hypothesis that long term writing computer supported activities can be associated with a progressive improvement of student's involvement and quality of productions, good student's results and performances as well as a good acceptance and attitude towards the tool and learning design.

3.6. Study 4: Writing about procedures

Goal. For the second activity, we worked with the new class of second year dental care apprentices and a new IT teacher. The purpose of this intervention was (1) to introduce the new platform to the new apprentices, (2) to test a different kind of writing activity implemented with a wiki and (3) to get useful information for future, more complex computer supported writing activities.

Method. The IT teacher suggested a scenario that was taking into account both our research and her course objectives. Apprentices were asked to contribute to an "Excel Guide" using the wiki functionality of the platform. The scenario had three steps. First, each student had to choose one of the several procedures proposed by the teacher and to write down the different steps of the procedure in a wiki page. Second, each student was asked to comment one of the colleagues' entries with the help of scaffolding questions already inserted in the associated "discussion page" (Hand, Prain and Yore, 2001; King, Staffieri and Adelgais, 1998). Third and last step, each student had to review and amend her own entry according to the commentaries received on the "discussion" page. However, due to lack of time, this third step could not be completed

and hence we were not able to measure the effect of comments by comparing the productions made the the first and last steps. The Wiki functionality was particularly relevant for this type of activity and came as an appropriate support for the pedagogic scenario and course objectives. As compared to blogs, two of the main advantages of the wiki application were: (1) the possibility to follow the modifications of every page in a chronological order (which is of interest to the teacher), the (2) scaffolded "discussion page" used for commentaries. In our study, this tool offered good enough support to implement this activity.

Results. Both the students and the teacher took interest in the use of the platform and took the exercise very seriously. For the qualitative analysis of the student entries in the wiki we used a modified SSQS scale (Six Subgroup Quality Scale) (Ransdell, S., & Levy, C. M., 1996). For the purpose of the study, the original scale was slightly modified by keeping only the most appropriate dimensions and by adding new ones that are more relevant. We analyzed both mastery of Excel software and the quality of the written productions. Firstly, we noticed that all students had a good knowledge of the various Excel procedures and functionalities. This came as a difficulty for an activity designed to help collaborative knowledge construction through commenting since there wasn't much to discuss about. Secondly, students particularly well adapted their written expression to the task and the context, although they did not receive any specific guidelines. They used proper written French instead of colloquial language. Contrary to these results, we nonetheless noticed that the text layout did not reach the same level of appropriateness. We believe this can be linked either to a lack of knowledge about the wiki's editing features or to the students' lack of developed structuring skills to organise their knowledge into a textual structure (i.e. the "translation step" Flower and Hayes, 1980). Finally, only a single comment was interesting, i.e. embedding an advice to the reader. All the others just commented that entry's contents were sufficient.

The quantitative analysis of the wiki entries shows that while students' initial productions were homogenous, large differences in size appeared in the commentaries. Only three out of seven students made comments. This can be explained by the low difficulty level of the task. Students had similar high knowledge levels and therefore not much intrinsic incentives to discuss.

Discussion. The results of this activity are similar to the ones of the first activity. On the one hand, the utilisation of the wiki tool proved to be very adapted to the requirements of the activity and students as well as the teacher found it easy to use and flexible. On the other hand, the educational activities could be improved on different points:

- Set up more difficult exercises where students have different skills levels and heterogeneous domain knowledge in order to obtain more relevant and elaborated comments from their colleagues;
- Leave more time for the commentary activity;
- Explain to a deeper extent the significance of this activity to the students;
- Scaffolding questions for the commenting activity need to be revised in order to simulate students' quality of comments.
-

3.7. Study 5: Writing from experience on procedures and instruments

Hypotheses. The previous studies helped us to adjust the ELGG environment to different learning designs as well as to identify the feasibility of short and long term, individual and collaborative writing activities. This fifth study took place mid February 2008. The goal was to propose actual written computer supported knowledge building activities to

the dental assistant apprentices. We hypothesised that "collaborative writing to learn" activities support subject matter comprehension by the means of reflexive thinking, epistemic monitoring and planning, translation, revision. This support should be reflected in the increased quality of the written productions. Secondly, we hypothesised that collaborative knowledge-building activities would be associated with good perceived satisfaction and learning from the students.

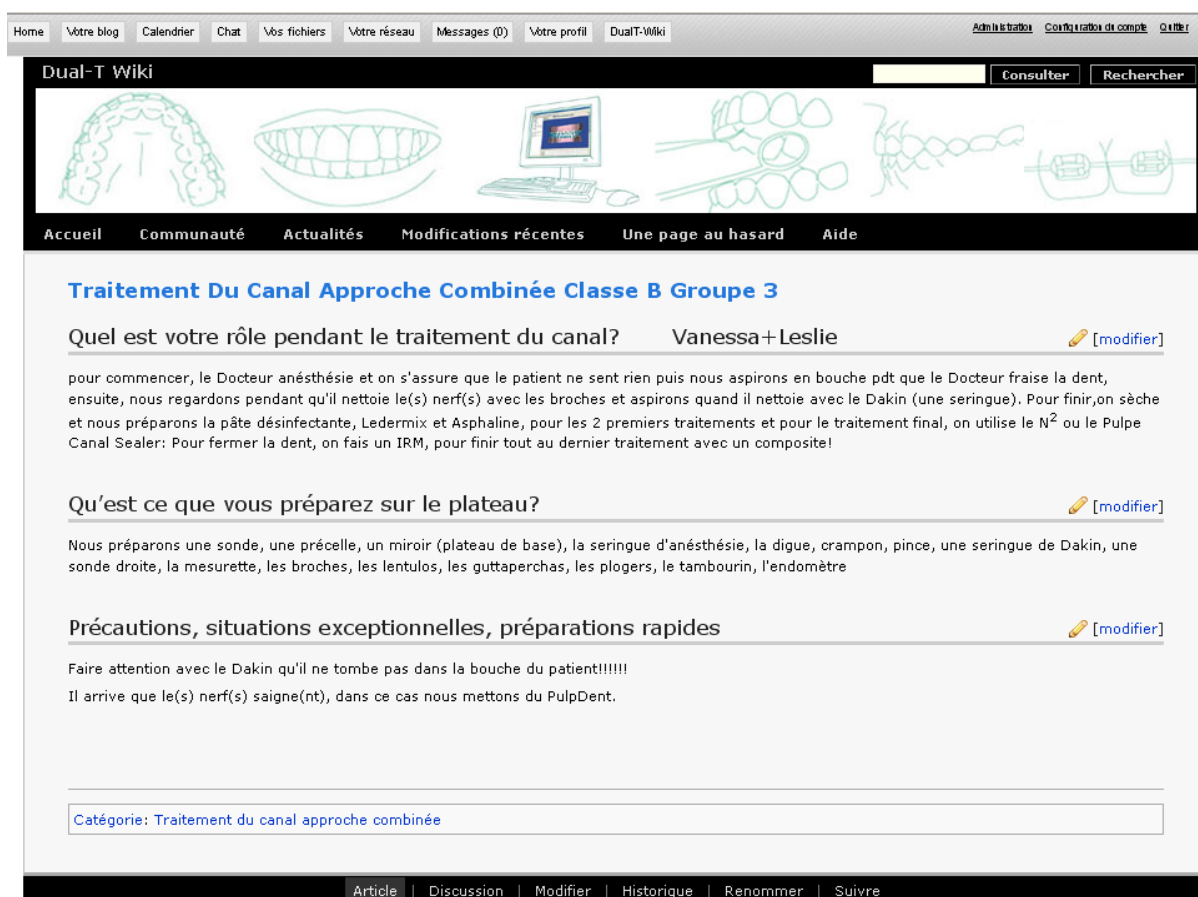


Figure 6: Screen capture of the wiki tool in ELGG

Method. The activity took place in the dentistry course and was co-designed with the speciality teacher. Students were set in small groups considering their experience with different medical procedures and instruments. Students using the same ones were put in the same group. They were asked to write about root canal work. The writing activity was strongly scaffolded and closely supervised by the teacher. Students had to answer to three main questions: "what is your role in a root canal treatment?", "what dentist instruments do you prepare on the tray for this kind of intervention" and "present some difficult, unusual situations linked to a root canal work and explain how they can be solved". They therefore used a wiki. The teacher followed online the advancement of the student's entries and answered their questions orally or using the "discussion" page of the wiki. When students finished this first task, the teacher projected all the entries one by one and discussed them with the class by pointing out the strong points as well as the mistakes or imprecision. He used this activity to clarify some important points of the root canal work.

Results. Due to the short laps of time between the study and the drafting of this report, the analysis of the data is still in progress. The variables we will measure are the

apprentice's comprehension of the procedure (root canal work), their perceived learning and their satisfaction about this alternative class. The comprehension of the root canal work procedures, will be assessed by the quality of the written productions as well as the oral comments of the teacher. The perceived learning and the course satisfaction have been measured with a questionnaire we built for this purpose and that consists of three dimensions: estimated learning, overall impression and evaluation of the computer environment. Finally, we will verify if the students' productions could constitute a knowledge database that could be reused in future activities.

3.8. Workplan for year 3

According to the design-based research approach, studies carried out in year 3 will refine the conjectures through repeated implementations of the learning design.

- *Study 6* is in preparation stage with the teacher of a radiology class. It consists in assessing the effect of peer-commenting on the understanding of procedures, as measured through the evolution of the quality of the text produced before and after commenting. As suggested by the advisory board of our leading house, in this activity not only will text be considered but also pictures. The activity will involve writing about spoilt digitalized X-rays: why is the X-ray spoilt and what was wrong in the procedure that caused the failure? Moreover, the activity will lead to the construction of a database on X-rays that can be re-consulted by the apprentices.
- *Study 7*. In contrast with the previous studies, study 7 will involve a long-term activity, over at least one month. Apprentices will conduct a journal-like activity on critical incidents regarding procedures and in commenting one another's entry with a scaffolding oriented towards the optimal resolution of the incident. Four to five entries will be written and commented on. The ELGG community blog will be used for this activity. Such activity is expected to improve apprentices' evaluation of critical incidents and ways of behaving in various problematic situations, as well as their estimated self-efficacy to face problematic situations.

Furthermore, contacts have been taken with other schools in Health and Social Care in order to replicate one of the tested designs in another context.

4. Project 3 (EPFL): Integrating technologies in heterogeneous contexts

4.1. Context

In 2006 and 2007, we conducted a field study in the domain of logistics training which revealed the following problem. At first sight, the dual system combines the better of two worlds, a deep immersion in authentic practice at the workplace and access to conceptual knowledge in schools. However, the organization of training over two separate places which emphasize action for the one (workplace) and theory for the other (school) poses the problem of the articulation of practical and conceptual knowledge. We use the terms “abstraction gap” to refer to the lack of a place where reflection on practice can be encouraged and supported. A dozen interviews realized at the outset of this study showed that the abstraction gap is created by both actors in the vocational system. Schools attempt to *teach* generalities: despite the efforts teachers invest in explaining and contextualizing textbook examples, apprentices are not able (or willing) to transfer generalities into their practice. School is described by apprenticeship masters (who are responsible for the apprentices in companies) as something irrelevant for the apprentice's daily practice. At the best, they recognize that conceptual knowledge might be useful in the later career of the apprentice. At the workplace, apprentices don't have the opportunity to apply the general skills they are taught in school. Especially in the beginning of their apprenticeship, apprentices are mostly involved in the manual aspects of the profession (e.g. moving boxes, packaging goods). Organizational decisions (e.g. about the layout of a new warehouse), which would require the application of theories taught in school, are taken by the employees already in place. In addition, intellectual work is sometimes negatively perceived in predominantly manual professions. This situation is far removed from the vision of apprentices learning in close relationship with their master by “watching over the shoulder” and masters modelling expertise and progressively scaffolding their support. Of course, help seeking and providing takes place daily between apprentices and regular employees in a company, but the help is more practical than didactical (see results of project 1).

The project concerns apprentices in logistics, a profession that involves the storage and transportation of goods (physical flow), the design of warehouses and transportation routes, as well as the management of inventories and information (information flow). The apprenticeship lasts for three years. A federal ordinance defines the profile of the profession as well as the competences to be acquired. We quote the definition of the profession from the ordinance to illustrate how physical activity (moving boxes and pallets) and intellectual activity (planning and organizing) complement each other:

Logisticians have aptitudes and skills which allow them to execute standard tasks in the domains of goods distribution, storage and transportation. They have to be able to counsel clients and elaborate communication and information processes. They also have practical and technical skills which are required to accomplish tasks autonomously and show interest in organization and planning tasks. (our translation from “Ordonnance sur la formation professionnelle initiale de Logisticienne / Logisticien avec certificat fédéral de capacité”, p. 1).

It is clear from this description that the goal of the logistician apprenticeship is not training mathematical engineers comfortable with queuing theory and operations management. However, apprentices should be able to understand processes and participate in organization and planning tasks.

4.2. Conjecture map

Our central research question is how can a combination of tangible computing (Fitzmaurice, 1996; Ishii & Ullmer, 1997) and fields of practice (Barab & Duffy, 2000) support the transition from workplace experience to conceptual knowledge and vice versa? This general research questions relies on four theoretical conjectures:

- A tabletop physical representation of the problem-solving context facilitates the apprentice's feeling of authenticity and purposefulness of the learning situation. A small-scale model of a warehouse allows learners to build an iconic representation of the problem (Bruner, 1966). This conjecture presupposes that the context for problem-solving is best represented by a physical three-dimensional model.
- Augmented reality facilitates the transition from experiential to conceptual knowledge through reflection. The projection of hidden variables which illustrates the simulated process on top of the physical model transforms these variables into objects for discussion. This conjecture relies on the assumption that learners use multiple representations (Ainsworth, 1999) of varying levels of abstraction to generalize and de-contextualize experience (Schön, 1987; von Glaserfeld, 1991).
- Fields of practice and ill-structured problems engage apprentices in problem-solving activities related to school curriculum and relevant for workplace practice. This conjecture relies on the hypothesis that the acquisition of conceptual knowledge is best organized through experiential learning in fields of practice (Barab & Duffy, 2000) which closely mimic real world situations, i.e. ill-structured problems (Jonassen, 1997) solved in a social setting.

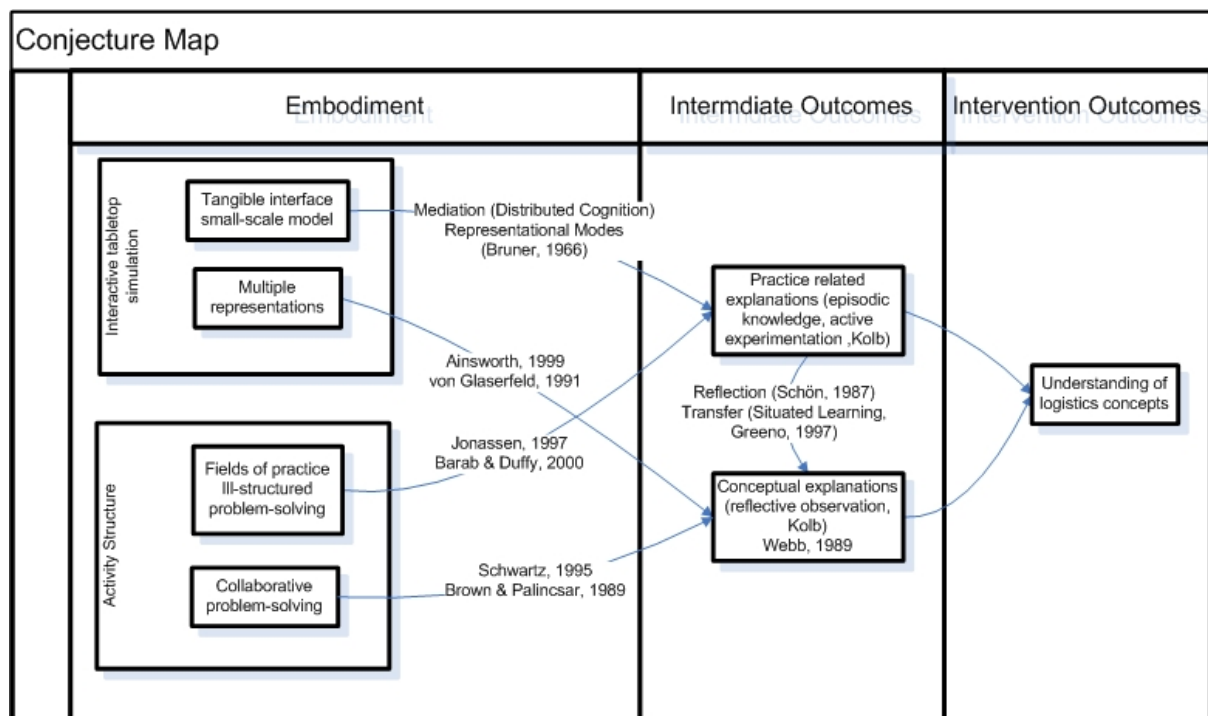


Figure 7 Interrelation of theoretical embodiments as well as their hypothesized effects upon interaction. Theoretical conjectures are represented by the arrows which link embodiments to intermediate outcomes.

- Collaborative interaction favors reflection upon experience. Self-reflection is a rather difficult skill for novice problem-solvers (Boshuizen, 2004). The interaction of several apprentices allows for a distribution of cognitive and meta-cognitive

functions (Brown & Palincsar, 1989). This conjecture addresses the positive effect of collaborative interaction on reflective activities and abstraction (Schwartz, 1995).

These four conjectures embody our current thinking about the rationale of the intervention that we co-design with teachers and set the theoretical context for the intervention. The conjecture map (see Figure 7) shows how cognitive and social learning mechanisms are determined by several design elements. The map will change as the investigation goes on and further insight is gained about the effects of the intervention. Theoretical conjectures are represented by the links from design embodiments to intermediate outcomes.

4.3. Main Study

Questions. We currently focus on conjecture 2 and conjecture 4 through an examination of the effect of the technological setup upon division of labour, turn-taking, spatial organization of collaboration and distribution of reflection activities. The specific questions we address are:

- Is there a spontaneous division of labor among apprentices and teachers when solving ill-defined warehouse design problems? What are the activities and roles that participants adopt? How is the division of labor enacted around the table?
- How and by whom is reflection enacted in the context of ill-defined problem solving activities? How do apprentices use their workplace experience to inform the definition and solution of the problem? How do teachers relate and translate concepts into the problem-solving situation?

Environment. Our investigation follows these "design based research" principles defined in section 1 rather than a series of tightly controlled studies. Therefore, at this point of the project, we do not base our quest for answers on the statistical refutation of hypotheses but on the iterative design and testing of a environment designed according to our conjectures. A large table (see Figure 8) covered with a whiteboard surface serves as a basis for collaborative problem-solving activities. The size of the table offers enough space to accommodate the simultaneous actions of four to five participants. Possible actions include the construction of a small-scale warehouse by placing wooden shelves on the table and the production of annotations and visual representations with genuine whiteboard markers. Besides wooden shelves, users can place metallic pillars on the table to represent architectural constraints (e.g. pillars to sustain the roof of the warehouse). Rectangular cardboard elements represent specialized areas of a warehouse (e.g. administrative offices and technical service rooms). The building elements for the model are scaled at 1:16 which allows the construction of a realistic warehouse (32 by 24 meters in reality).

This physical small-scale model of a warehouse is augmented through a video projector and a mirror placed above the table (figure 8). A gallows carries the camera, the video projector and the mirror. The purpose of the mirror is to augment the distance between the projector and the table, in order for the projection to cover the whole surface of the table. All objects (shelves, pillars, cardboard) are tagged with fiducial markers (similar to a 2 dimensional bar code) to enable the camera to track their position on the table (Fiala, 2005). The information provided by the camera about the precise position of the objects on the table enables the system to project graphical representations (augmentations) on top and around the objects. In addition, the position of objects is used to configure a simulation to test the warehouse under realistic conditions. The simulation includes a warehouse management simulation which responds to customer orders and reorders items as the storage levels become too small. The movement of goods is simulated by the movement of a set of forklifts.



Figure 8. Left: the table (2 x 1.5 m) and the gallows (2.6 m high). Wooden shelves are arranged on the table. Right: Apprentices draw a forklift's path on the warehouse floor.

We implemented two types of augmentations that can be used on top of the small-scale model. The first type addresses the physical layout of the warehouse and the second type concerns the logistic processes which take place in the warehouse.

- *Physical Layout.* The construction of a warehouse consists of laying out shelves by taking various constraints into account. The optimal width of alleys for example depends on the type of forklift, on specific security rules, and on the type of shelves that are used. Besides the choice of a general strategy (many short alleys versus few long alleys), the implementation of a warehouse relies on a sequence of distance measurements and topographic arrangements (respecting constraints of co-linearity or perpendicularity). To support this activity, we developed two augmentations. The *Simple Grid* consists of displaying an equally spaced grid on the floor of the warehouse. The width of each square represents one meter. The *Dynamic Grid* is a more sophisticated version of this augmentation displays whether items stored in a particular shelf are accessible by a forklift (the forklift has to be able to rotate in front of the shelf to pick the item). Small dots displayed next to the shelf indicate sufficient storage space (green dots) or insufficient space (red dots).
- *Logistics Process.* The second type of augmentation consists in making visible some logistic variables which are normally invisible. These variables concern the "information flow" which is associated to the physical movement of goods in the warehouse. We developed three distinct visualizations that are projected on top of the shelves in a 3x3 table. The cells in the table represent the nine possible storage slots in a shelf (i.e. nine pallets can be placed in a shelf). We developed three augmentations: *Slot content* (Figure 9, right) represents the item type stored in each slot is represented by a distinct color (e.g. red for strawberries, yellow for bananas, etc.). *Slot rotation rate* represents the frequency at which a shelf's content changes by a color gradient that represents a continuum from high frequency of movement (dark red) to low frequency of movement (light red). *ABC analysis* (Figure 9, left) shows the from an "ABC analysis" color codes and letters that represent the A, B and C areas in green, yellow and red respectively. The "ABC analysis" determines three types of storage areas, based on the cost of items and the frequency of their movements.

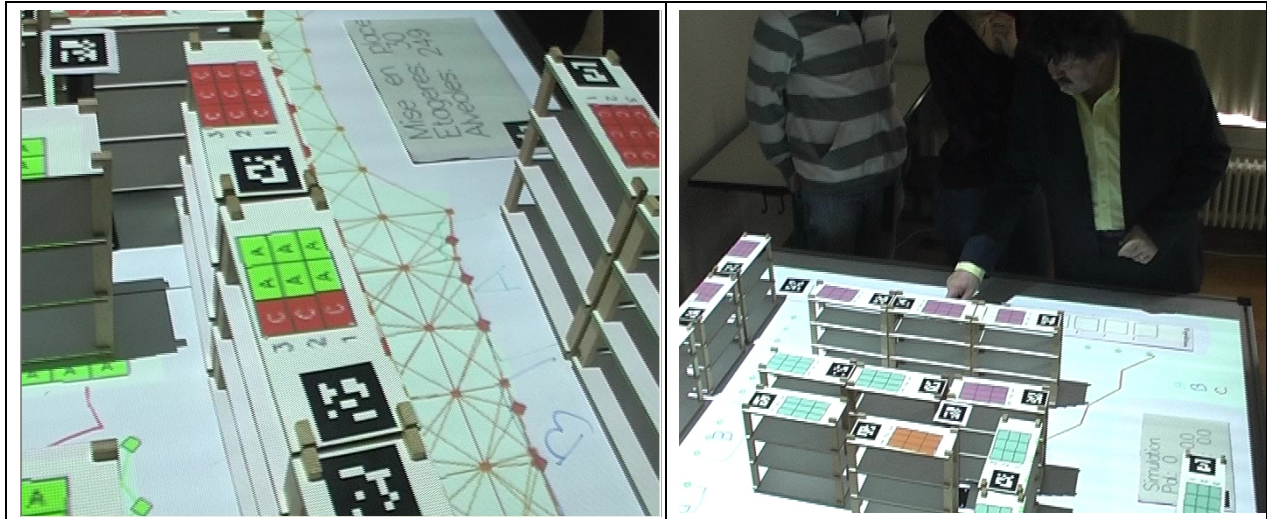


Figure 9. Left: ABC analysis augmentation. The color of the slots beamed on top of the shelves represents the A, B and C zones in the warehouse. On the floor, one can see annotations done by the apprentices (letter "B" on the bottom right). Right: Slot content and simulation output projected on top of the shelves. The line on the right side represents the path followed by a forklift.

Methods. The interactive table has been tested on three occasions with a total of six groups of apprentices. The three occasions differ regarding the location, the definition of the problem, the augmentations available to the participants, the presence and the number of teachers. The sessions all started with a warehouse layout problem. We used these initial layout tasks (from 10 to 30 minutes) as a basis for comparison. Each session was videotaped and sound was recorded with ad hoc digital recorders. In sessions 2 and 3, one camera captured the table from above and two cameras were placed around the table to capture the general scene. One to two researchers were also present during the sessions and were taking notes to document the session. A debriefing session with the teachers took place at the end of the sessions.

Results for question 1: Is there a spontaneous division of labour among apprentices and teachers when solving ill-defined warehouse design problems? What are the activities and roles that participants adopt? How is the division of labor enacted around the table? The analysis of interactions is still ongoing at the time of writing this intermediary report. We therefore report preliminary results which will be refined in the future.

To answer these questions, we report an analysis concerning groups 4 and 5 in session 3. The session was organized by splitting up the class into three groups of apprentices. The task consisted of laying out a warehouse so as to maximize the number of slots available for storage. The number of slots accessible by forklifts was projected on top of the office space in the warehouse. Four pillars were placed on the floor to represent architectural constraints. Group 4 started the activity around the table while group 5 watched and commented a computerized top view of the warehouse projected at the other end of the classroom. After group 4 completed the assignment, group 5 was given the challenge to find a better solution. At the end of the session the teacher compared the 2 solutions, and discussed in depth the advantages and disadvantages of the solutions. During this debriefing, the teacher linked the layouts produced by the apprentices to general logistic concepts (what type of warehouse is required for different types of businesses, which layout is more appropriate for what type of forklift).

Table 3. *Summary of observations according to the type of augmentation used and the constraints imposed on the problem definition.*

<i>Session</i>	<i>Group</i>	<i>Location</i>	<i>Augmentations</i>	<i>Constraints</i>	<i>Description</i>
1	1	Professional school	None	None / Pillars	Activity took place on smaller tables (1x1.5m) with wooden shelves but without computer support.
2	2	University	Simple grid	Office space 96 m2	
	3	University	Simple grid	Office space 96m2 / Pillars / Storage business	
3	4	Classroom	Dynamic grid / office	Pillars / Office space predetermined	Group 5 and 6 are in the same classroom and observe group 4's activity projected on a screen.
	5	Classroom	Dynamic grid / office	Pillars / Office space predetermined	Competitive setup, group 5 is asked to "do better" than group 4.
	6	Classroom	ABC analysis	Layout from group 5	Group 6 analyses the layout produced by group 5.

We analyzed interactions second by second. For each second and for each participant we coded whether the participant was talking or acting. We also identified the position around the table by splitting the periphery of the table into 6 segments labelled from 1 to 6 (See Figure 10, bottom). The raw data stemming from the coding can be represented on a timeline (See Figure 10 **Erreur ! Source du renvoi introuvable.**, above) to facilitate the visual detection of problem-solving phases. The close observation of the graphic (which would require a larger print than is possible here) shows two implementation phases which are separated by a discussion. The representation lends itself to a quick identification of the most active speakers and implementers and is useful to ground and anchor a more narrative account of the interaction. The timeline offers a first glimpse at the interaction. To deepen our understanding of collaboration dynamic we use more local or more specific data.

Figure 11 shows the difference of collaboration patterns between groups 4 and 5. In group 4, the contributions to building the warehouse were rather equilibrated: A4 and A2 both brought shelves to the table (shelves were stored on a nearby table). From the ADD pie chart we see that A4 often handed the shelves to his peers while A2 also placed them by himself on the table. A1 appear as the main thinker as he did half of the MOVE actions but his peers were also involved. In group 5, the distribution was much more uneven. One apprentice (A3) took the role of the "boss": he was giving orders to his peers but did about no action. He only added 3 shelves and never moved one. A4 did all of the GET actions, bringing the shelves to the table and placing a significant part of them by himself (ADD actions). The movements of existing shelves were mostly taken over by A1 and A2.

Complementary analyses of the distribution of speech time confirm this difference (figure 102). In group 4, A1 did not participate much in the discussion. After listening to the dialogue, we found that A2 took over the most reflective role while participating in the implementation as well. The collaboration is different in group 5 because A3 took a very dominant position. One apprentice (A1) did not participate much in the dialogue.

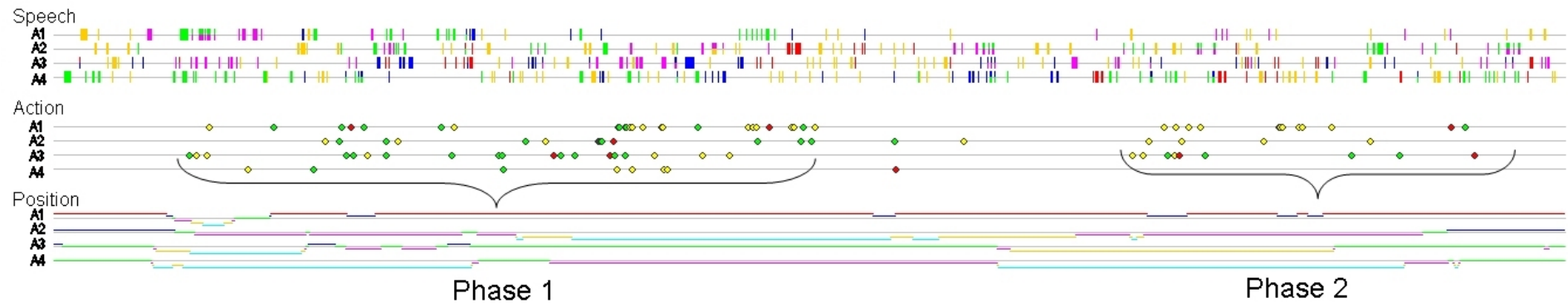
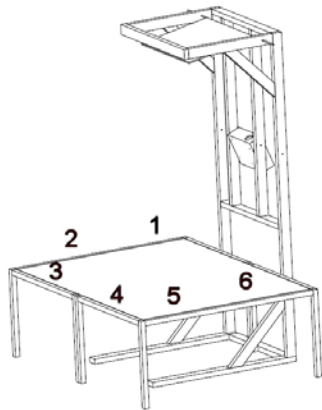


Figure 10. Timeline of collaboration for group 5.

Three sets of lines represent Speech, Actions and Position of apprentices around the table. Each line inside a set represents one apprentice (labelled A1 to A4).

- Speech: one vertical bar corresponds to an apprentice speaking for one second. The colour of the bars represents who the apprentice has been speaking to (red=A1; blue=A2; green=A3; yellow=A4; magenta=all) .
- Action: dots represent different manipulations of the shelves (green=add object on the table; yellow=move an object ; red=delete an object).
- Position: each line represents the positions of one apprentice around the table (see code for positions on the left). The level of a line corresponds to the position around the table. The highest level on the timeline corresponds to position 1 and the lowest value corresponds to position 6. It appears from the graph that A1 mainly stayed at position 1 and that A2 and A3 were the most mobile apprentices in this example.



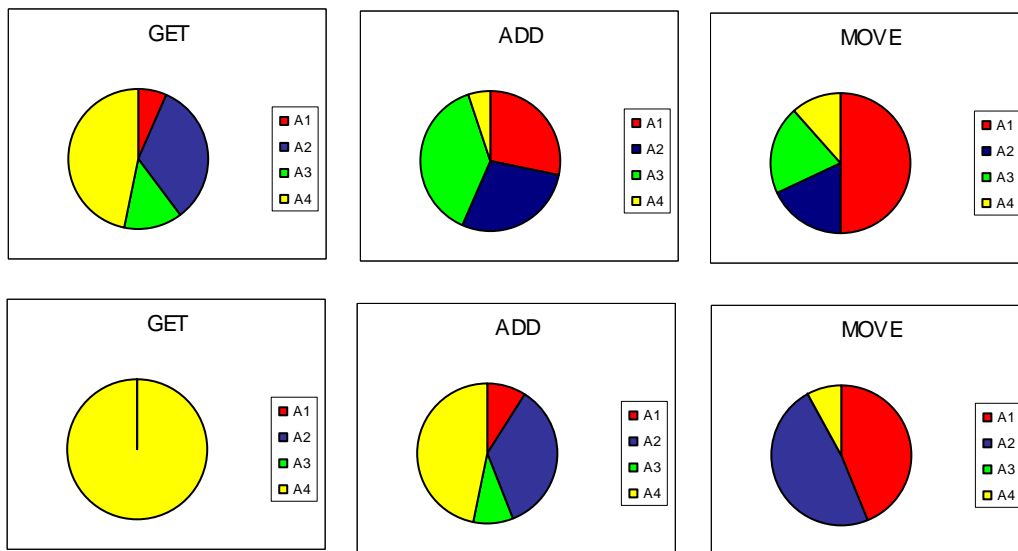


Figure 11. Distribution of action types in group 4 (above) and 5 (below). A1 to A4 correspond to the four apprentices

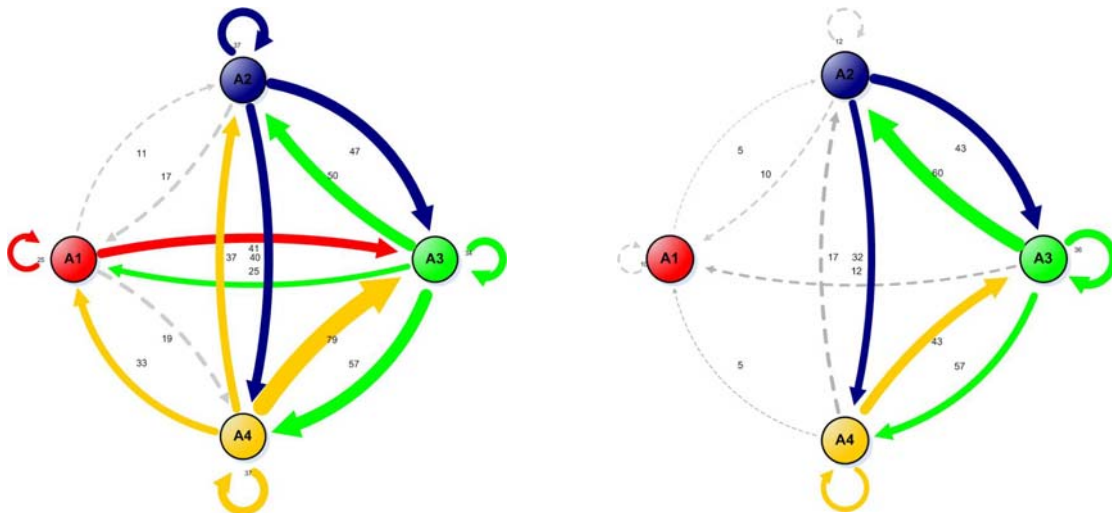


Figure 12. Collabograms for group 4 (left) and group 5 (right). The transitions show the number of seconds each apprentice spent talking to whom. Reflexive arrows represent speech addressed to the whole group.

Results for question 2. How and by whom is reflection enacted in the context of ill-defined problem solving activities? How do apprentices use their workplace experience to inform the definition and solution of the problem? How do teachers relate and translate concepts into the problem-solving situation. We use data from sessions 1 and 2 to answer these questions. A detailed account is underway at the time of writing.

Session 1 took place at the professional school and used only wooden shelves without computer based tracking and augmentation. The goal of the session was to observe what kind of actions the wooden shelves and plastic pallets afford for apprentices. Five apprentices participated to the session which lasted for two hours. We asked them to lay out the best possible warehouse on one of two side-by-side horizontal whiteboards. The apprentices started right away to place shelves on the table. One of the teachers intervened shortly after the beginning of the activity to ask about the criteria for placing shelves. The ideal dimension of a corridor corresponds to one forklift length (2.5 meters) plus a security zone (twice 0.5 meter). The teacher had taught this constraint during the week preceding the session. Apprentices spontaneously asked about the scaling of the shelves (1:16) and started computing the equivalent of one meter in the small-scale.

However, the apprentices were uneasy with executing the computation mentally (it consisted of dividing 100 by 16 and then multiplying the result by 3.5). The teacher intervened and proposed to use the pallet as a measuring unit. He first asked about the size of the pallet in real dimensions (euro pallets have a standard dimension of 120 by 80 cm). After some hinting by the teacher, one of the apprentices proposed to use three pallets length (3.6 m) to approximate the ideal 3.5 meters corridor width. Apprentices immediately adopted this method and used the small plastic pallets to lay out the shelves. This example illustrates how "reflection in action" takes place during problem-solving. In this case, the teacher helped reinterpret the arithmetic scaling problem as a practical measurement problem.

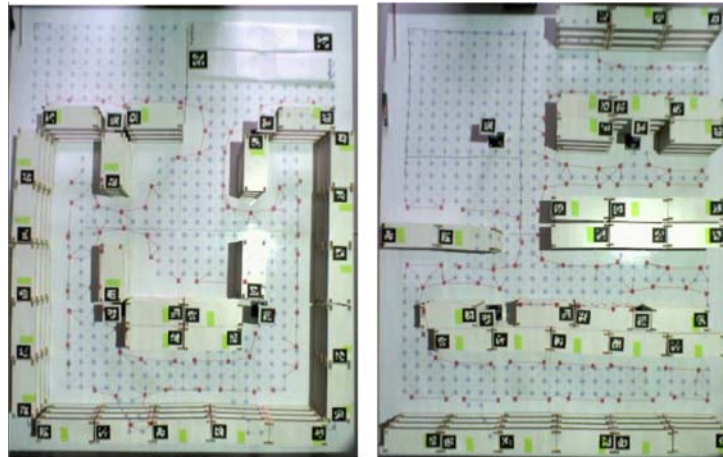


Figure 13. Layouts from session 2. Apprentices lay out a warehouse (left) and modify the design after discussing with the teacher (right).

The second session took place at EPFL and included the functional augmented tabletop environment. Two groups of respectively four and five apprentices and their two teachers worked for three hours with the material. The first task was similar to the first session: create an efficient warehouse by placing as many shelves as possible in the available area. In addition, apprentices had to take constraints into account: the surface dedicated to administration had to equal 48 square meters. Also, four metallic pillars were placed by the teachers on the table to represent architectural constraints. After completing the first layout (see Figure 13, left), the teachers critiqued the layout by asking the apprentices whether the warehouse was easy to navigate, was built following security rules, allowed enough free storage, etc. The discussion led to the conclusion that one could place a pillar inside the administrative area without violating the surface constraint and that the area did not need to be rectangular to satisfy the 48 square meters constraint. The second layout (see Figure 13, right) took this conclusion into account and resulted in a better layout from the navigation point of view as well as from the number of shelves. This example illustrates "reflection on action", during an intermediary debriefing. The teacher's critique redefined the framing of the problem (an administrative area does not need to be completely without obstacles) and highlighted the critical dimensions for the quality of a warehouse (ease of navigation). This more specific problem definition helped the apprentices build a more efficient solution.

Discussion. Concerning question 1, our analyses have shown that there is a spontaneous division of labor among apprentices during problem-solving. This has potentially positive as well as negative effects. On the positive side, the distribution of roles allows one apprentice to take some distance and offer reflective comments. This is similar to the spontaneous division of labor which happens when two people use a computer (Miyake, 1986): one becomes the "doer" while the other becomes the "thinker". The negative effect of division of labor is that in each of the two cases we analyzed, one apprentice

was left alone. A similar problem arose during session 2 and teachers reacted to the disequilibrium by assigning tasks and roles to the apprentices. We will encourage the teachers to foresee potential participation inequalities and evaluate whether roles can be assigned to apprentices at the outset of the activity. To our sense, visualizations of the division of labor are very efficient to get a sense of interaction dynamics. However, they should be complemented with analyses of the actual content of interaction to enable a deeper understanding of learning processes.

Concerning question 2 we identified two types of reflective activities. One takes place during the activity and the other takes place afterwards during debriefing. In the sessions that we observed, the teachers clearly drive the reflection process. Apprentices mostly accompany their actions with poorly elaborated verbalization. On some occasions (e.g. group 4) one apprentice takes a more proactive role by regularly questioning the quality of the solution and envisaging alternative ways of doing. Teachers typically interrupt the problem-solving process by asking “why” questions to the apprentices which trigger explanations and design justifications. It is interesting to notice that apprentices tend to react to practical problems by using school strategies. Given the constraint of a 48 square meters surface, they drew a rectangle, given a scaling problem, they started “doing divisions”. In both instances, the teachers were able to propose a realistic solution: use pallets to measure distances, arrange the administrative surface so that it doesn’t take up too much valuable storage space. These are instances of “making expert thinking visible” (Collins, Brown & Holum, 1991): the teacher models the translation of theory and conceptual knowledge into the resolution of an authentic problem. In such a situation, the teacher’s status changes from a sage on the stage to a more experienced colleague in the warehouse. During debriefing, teachers adopt a more traditional role, using logistics concepts to critique solutions by the apprentices.

4.4. Work plan for year 3

Authentic use in classroom. The sessions we have conducted so far were initiated by us. Now that a table is installed in a classroom of the professional school, the teachers have the freedom to use it whenever they feel it is appropriate. They are working on the development of ten lessons which cover a wide range of logistics concepts and problems. This includes the preparation of lesson plans and the transformation of traditional exercises into problem-solving situations. In parallel, we are developing augmentations which correspond to the pedagogical objectives of the lessons. The general design principle that we follow for new augmentations is that they should support analytical thinking on and about the warehouse and the results from the simulation.

Portable version. We hypothesize that the size of the table influences the perception of the warehouse model by the apprentices. A large table enables distributed team work, apprentices and teachers moving around the perimeter. A smaller version of the warehouse model might foster a different approach to the problem. We are developing a version scaled at 1:50 that can be used on a regular classroom table. As a positive side-effect, the diffusion of the system that we developed in other schools would be facilitated with a smaller and more portable version. The question of the reduction of the cost for a smaller version remains open and presents a technological challenge by itself.

Reusable representations.

Reflection takes place on re-presentations of previous activities. We will develop functionalities for saving and reusing warehouse layouts built during a lesson. The system will index these traces with relevant data (time, participants) and make them available for future debriefing, or sharing among groups and classes. We plan to use the Elgg platform (project 2) to facilitate the online elaboration of such activity traces.

5. Training young researchers scientists

	<i>Name</i>	<i>Activities</i>
1	Matthieu Calame Université de Fribourg	Project 1 + PhD in Education <i>Has left the project in Summer 2007</i>
2	Monica Gavrota Université de Genève	Project 2 + PhD in Education
3	Guillaume Zufferey EPFL	Project 3 + PhD in Computer Science
4	Anya Hitz Mourad Université de Fribourg	Project 1
5	Bernardo de Rocha Trindade Université de Fribourg	Project 1

One more PhD student will be hired soon by EPFL. During this second year, the young scientists and the senior members of the leading house met every month, for internal meeting and other events. After the doctoral events from the first year (see below) , we had 3 events in 2007:

- A 3 days workshop on design-based research (see section 6)
- Participation to a workshop given at the University of Geneva by Stephen Billett (Griffith University, Australia).
- The 2 days annual workshop of the leading house
- Structural equation modeling (SEM) course at Methods in the Social Sciences Swiss Summer School (one student)

The young researchers have been associated with all activities of the leading house, including all meetings and all publications. Their publications are hence listed in section 8. We also send the young researchers to several international events listed below.

6. Overview of year 2 activities

- The many school visits workplace visits for observations and/or interventions are not listed here but described within each individual project reports.
- 8 leading house internal meetings
- A 2.5 days course on design-based research given by Prof. William Sandoval (UCLA), on June 20-22nd 2007, on EPFL campus. The course was attended by all leading house members as well has 5 external guests. All projects were presented and discussed.
- A 2.5 days residential seminar (Villars, February 4th – 6th 2007) with all leading house members, including the members of project 4, plus the members of the advisory board and 1 external guest.
- Five members of Dual-T participated to the Leading Houses Congress organized by the steering committee in Yverdon on May 31st and June 1st 2007. The work of Dual-T has been presented.
- We organized the call for proposals and following the internal and external review as well a several meetings with SFIVET for negotiating the scope.
- Our work was presented in several international conferences:
Gavota, M., Bétrancourt, M. Schneider, D. K., & Richle, U. (2007). Favoriser l'apprentissage en mutualisant l'expérience pré-professionnelle: étude et conception préliminaires. Communication à la treizième journée d'étude sur le

traitement cognitif de systèmes d'informations complexes, JETCSIC 2007, Metz, 6 juillet 2007.

Gurtner, J.-L. "What do apprentices really learn at the workplace?" University of Geneva, 2.11.2007.

Gurtner, J.-L. Seeking help over the mobile phone: a solution for apprentices at work? 12th Biennial Conference for Research on Learning and Instruction, Budapest, Hungary 30.08.2007.

7. Publications

Gavota, M., Bétrancourt, M. Schneider, D.K., & Richle, U. (To appear). Computer supported collaborative writing (CSCWr) in vocational education, To appear in *Proceedings of the EARLI SIG Writing conference 2008*, June 11-13, Lund, Sweden.

Gavota, M., Schneider, D. K., Betrancourt, M., & Richle, U. (To appear). A technology-enhanced learning environment to support learning by sharing professional experience in writing, To appear in *Proceedings of EdMedia 2008, World Conference on Educational Multimedia, Hypermedia and Telecommunications*, June 30 - July 4, Vienna, Austria.

Gurtner, J.-L., Calame, M., Hitz, A., & de Rocha Trindade, B. (to appear) Seeking and receiving help at the workplace. The potential of M-learning devices, *Computers & Education*,

Jermann, P., Zufferey, G., & Dillenbourg, P. (submitted). Bridging the abstraction gap: an account of tangible computing in vocational training. *Vocations and Learning*

Richle, U., Schneider, D. K., Gavota, M., & Betrancourt, M. (To appear) Social software in the context of vocational training, To appear in *Proceedings of EdMedia 2008, World Conference on Educational Multimedia, Hypermedia and Telecommunications*, June 30 - July 4, Vienna, Austria.

Zufferey, G., Jermann, P., & Dillenbourg, P. (To appear) A tabletop learning environment for logistics assistants: activating teachers. *The Third IASTED International Conference on Human-Computer Interaction (IASTED-HCI 2008)*, 17-19 March 2008, Innsbruck, Austria

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Appendix 1 : Typology of help requests (project 1)

Apprentice requires help from a colleague to check the car blinkers.	<i>Physical help cooperation</i>
Apprentice checks a car. He hears a whistle near the exhaust pipe. He requires help from one of his colleagues to tell him, what he thinks.	<i>Solicitation needed advice</i>
Apprentice has to change the wheels of a 4x4 car. The apprentice notices that the wheels have special rims that need a special pressure. At that time, the wheels don't have this special pressure. The apprentice asks for supplementary informations to know who changed the wheels and put the wrong pressure.	<i>Solicitation needed supplementary</i>
Apprentice needs to replace the wipers. He goes to the Parts Dept and asks colleague there to hand him a new pair of wipers.	<i>Material : part acquisition</i>
Apprentice asks colleague next to him whether he could borrow a specific tool.	<i>Material : borrow</i>
Apprentice has to put some gaz in the car. He asks for the autorisation to do it.	<i>Autorisation</i>
Apprentice does not know which type of screws is needed for that type of wheels.	<i>Technical information needed</i>
Apprentice does not know whether he should bring the car back to the customer when work is done.	<i>Planning information needed</i>
Apprentice does not know how to reinstall a brake disk; colleague does it for him.	<i>Intervention needed: delegation</i>
Apprentice does not know how to purge the cooling system; both end up doing it together.	<i>Intervention needed: cooperation</i>
Apprentice asks an other apprentice to lift the car his working on instead of him.	<i>Physical help substitution</i>