An Active Learning and Training Environment for Database Programming

Claus Pahl and Claire Kenny
Dublin City University
School of Computing
Dublin 9, Ireland
[cpahl|ckenny]@computing.dcu.ie

Abstract: Active learning facilitated through interactive, self-controlled learning environments differs substantially from traditional instructor-oriented, classroom-based teaching. We present a tool for database programming that integrates knowledge learning and skills training. How these tools are used most effectively is still an open question. Therefore, we discuss analysis and evaluation of these Web-based environments focusing on different aspects of learning behaviour and tool usage. Motivation, acceptance of the learning approach, learning organisation and actual tool usage are aspects of behaviour that require different techniques to be used.

Motivation

In recent times, our understanding of learning has changed. We base our learning and teaching approaches on assumptions that often contradict traditional thinking (Grabinger, 1996). We now understand learners as active constructors of knowledge. We realise that skills and knowledge are best acquired within realistic contexts. We look at Computer Science undergraduate education here. In particular in this subject, the combination of conceptual knowledge and practical skills is often of paramount importance. Execution models and abstract software development paradigms on the one hand and programming on the other hand are examples that illustrate this point. We can often distinguish between classical conceptual knowledge-oriented learning and skills-oriented training.

We will present an interactive learning and training environment here. This environment supports the SQL (Structured Query Language) part of a database courseware system (Pahl, Barrett, & Kenny, 2004). It aims at providing students with an environment that integrates the broad range of aspects needed to become a knowledgeable and skilled database programmer. Active learning and a realistic environment are the essential aims. Instructional design for this type of environment is still an area of active research and the learner behaviour in these systems is not well understood. The analysis of learner behaviour in these systems will therefore form a substantial part of our system presentation. We will discuss a combination of survey and Web usage mining techniques here.

Our main objective in this paper is the description of this learning and training environment. We will describe the system as it is used by the students and we discuss the relationship of the instructional design to theoretical principles. We will address the students' learning behaviour in these types of environments. The effectiveness of the environment will also be briefly addressed. We end with a discussion of environment and approach underlying it.

An Interactive Learning and Training Environment

System Overview

The interactive SQL learning and training environment is embedded into an online courseware system – called IDLE (Pahl, Barrett, & Kenny, 2004) – for a second year undergraduate database course. The SQL part forms a central part of this course as database programming is one of the core learning objectives of the course. Programming (i.e. defining, updating, and querying database tables) is a skill. Programming skills need to be trained. Moreover, we see this course also as an introduction to database engineering. Therefore, understanding and mastering the overall development process of a database application is equally important. Database programming in

SQL also requires conceptual understanding of the underlying data model with its structures, operations, and constraints.

The central characteristic of the system is its coherent integration of different aspects and activities relevant in the context of database development and programming. We provide four different features for the different aspects of SQL programming:

- Conceptual knowledge. Conceptual knowledge is presented in a virtual lecture system.
- Procedural knowledge. SQL and parts of its underlying data model are about the execution of instructions. Procedural knowledge is presented in an animated tutorial system.
- Programming skills. SQL programming is the core activity, supported by an interactive tutorial that guides the student through exercises to be worked on within the system.
- Development skills. SQL programming is part of the overall database application development process, which is supported by an integrated lab environment with modelling, programming, and analysis features.

The system is implemented as a Web-based system, i.e. only a Web-browser and standard plug-ins are required by the student.

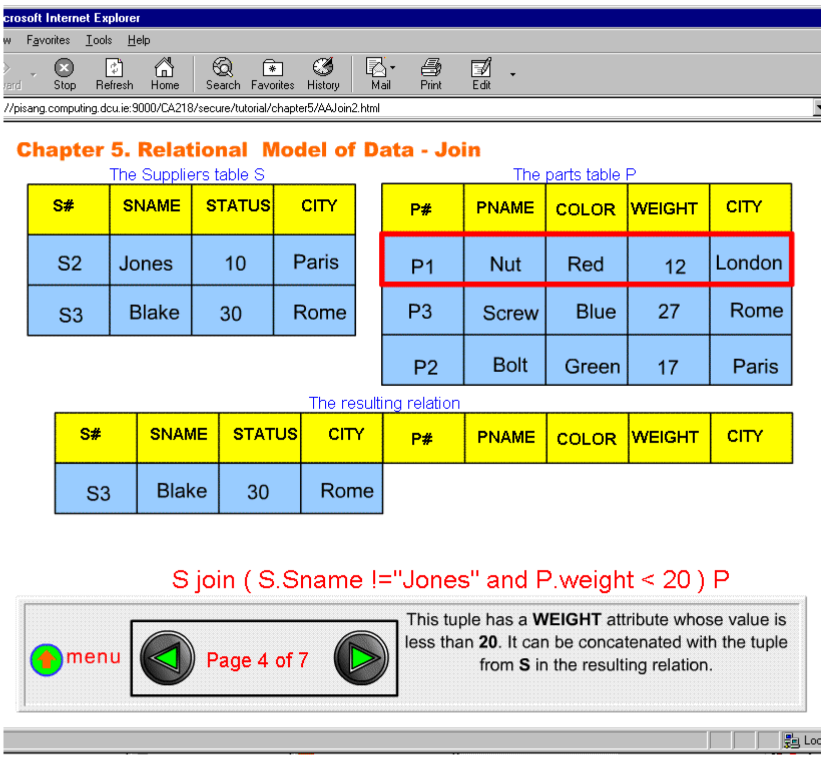

Figure 1. Lectures – synchronised audio-visual presentation.

Conceptual Knowledge

The students use an audio-visual presentation that presents the conceptual background. Recorded speech of the lecturer is synchronised with material in overhead form. Students can control this lecture-style presentation through the usual interactive features of an audio player (Fig. 1).

Procedural Knowledge

SQL is a language that implements different database definition and manipulation operations. An animated tutorial using Flash animations illustrates the execution of these operations in a step-by-step fashion using examples (Fig. 2). Students can execute these operations in small steps. Animated tutorials are particularly useful to illustrate operations that are sometimes conceptually difficult to understand. These include for instance the combination of database tables using a join-operator or partitioning of tables using the SQL group-by-operator.

Programming Skills

SQL queries are usually more complex and difficult to formulate than any of the other SQL operations. We have supported queries through an interactive tutorial (Fig. 3). The tutorial guides a student through a sequence of exercises with increasing difficulty. Each unit addresses a particular aspect of SQL querying. The feature provides an input interface for each exercise where a student can type in an SQL solution and submit this solution to a remote database server that executes the query and returns the result. Syntactic and semantic feedback is available. This feature provides links to the relevant background material (conceptual and procedural knowledge features).

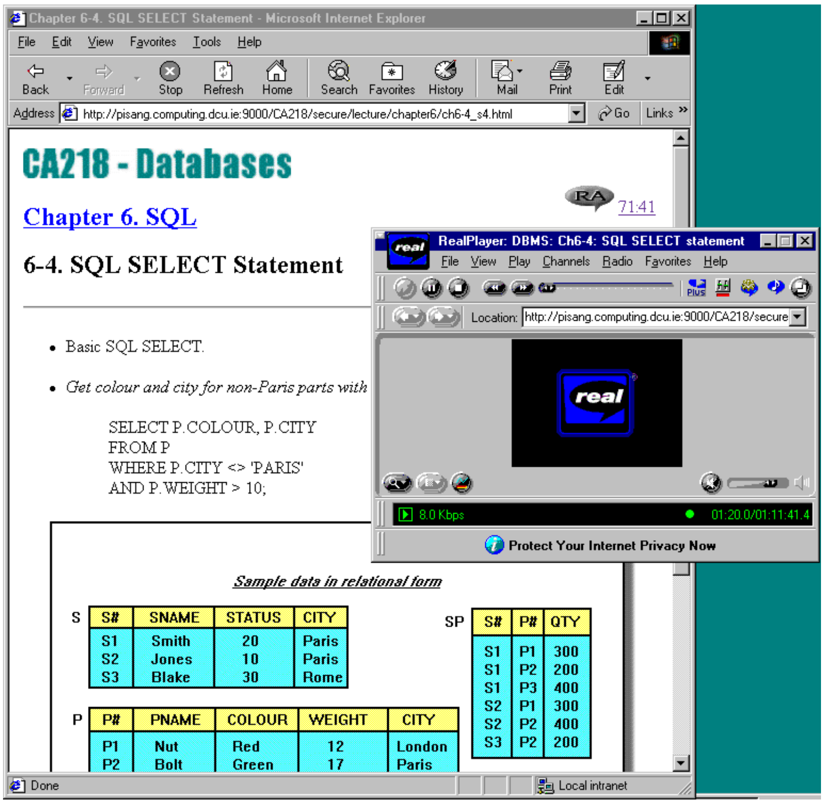

Figure 2. Animated Tutorial – operator animation.

Development Skills

The development of a database application is a multi-stage process including the stages of modelling (in Entity-Relationship notation), programming (in SQL), and analysis and optimisation (using normalisation). The database course environment provides interactive, integrated lab features for all three activities. The students are provided with a workspace in which they can create and store a data model. This can be translated into an SQL table representation, which in turn can be accessed through a manipulation interface where these tables can be used to work on projects and other coursework (Fig. 4). The table definitions can also be loaded into a normalisation tool. An integrated, realistic lab environment that resembles features of database development environments is the central feature.

Using the Environment

Conceptual understanding of principles and concepts of the topic is of course required before practical work can start. However, the aim of the tutorial system is to allow students to go quickly into the practical features by supporting a learning by discovery style, allowing them to acquire skills, but also to construct and deepen their conceptual knowledge through activities in meaningful and realistic problems. Consequently, the practical features are well linked to the respective background.

Active Learning and Training

Active learning plays an important role in recent instructional design approaches. Learning is seen as a process in which learners actively construct knowledge and acquire skills. In the context of computer-supported interactive learning and training environments, the role of this computer environment needs to be defined. The environment is a tool that mediates the interaction between learner and content.

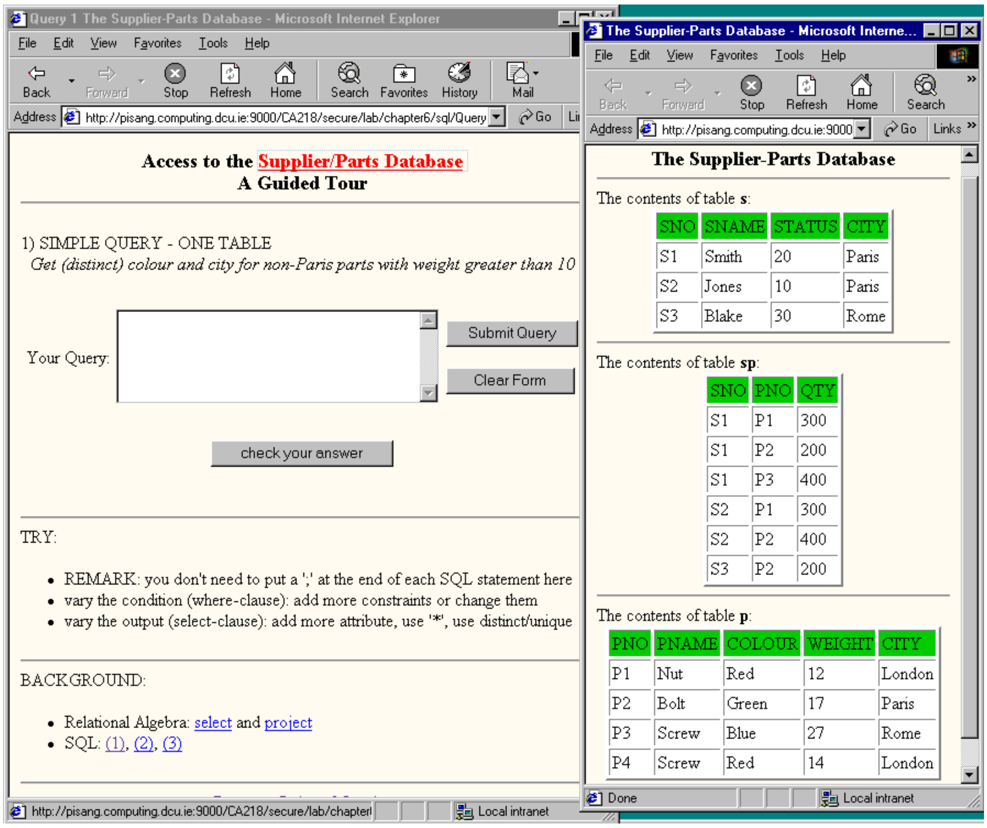

Figure 3. Interactive Tutorial – SQL execution.

Activity theory is a conceptual framework that can describe the structure, development, and context of computer-supported activities (Nardi, 1997). The emphasis on the interaction between learners and their environment explains the principle of tool mediation. Tools shape the way humans interact with reality. Educational tools reflect experiences learners and instructors have made in trying to solve particular problems. The students should be engaged in solving meaningful problems in an activity-based, realistic setting.

In our case, database application development provides a meaningful problem. The courseware system is designed along some of the principles of activity theory – we will ignore the social perspective here since our focus is on learner-content interaction. The database courseware system creates a realistic setting by integrating tools into a learning and training environment that resemble tools of a real database development environment. In particular the tutorial and lab support features are tools in the activity theory sense, shaped by the experience of developers and instructors. They support modelling and programming problems, i.e. the developer's perspective, but they also incorporate the instructor's experience in teaching the topic over several years. Modelling, programming, and analysis features interacting with an enterprise-scale database server provide the realistic setting here. These features are enhanced by the inclusion of instructional functionality (guidance and feedback).

The backbone of the instructional aspects of the SQL environment is characterised as follows:

- The active participation of students is essential. Students can create and populate database tables and execute queries.
- Active construction of knowledge and skills results in an increased ownership of students in the learning process.
- Meaningful projects allow students to acquire skills and experience in database programming and development.
- A realistic setting improves the learning experience and demonstrates the applicability of knowledge and skills.
- Guidance and feedback provide instructional support in the environment.

Activities such as programming are at the centre of our learning and training environment. However, supporting learners through scaffolding is essential from the instructional perspective (Guzdial & Kehoe, 1998). In addition to just mediating between students and database tools, the environment must fulfil functions of the instructor.

- The environment replaces the instructor with a virtual master that guides learners through exercises and that provides immediate feedback on activities.
- Each activity needs to be complemented by links to the background (conceptual and procedural knowledge in the form of virtual lectures and animated tutorials) relevant and problem-related for the activity in question.

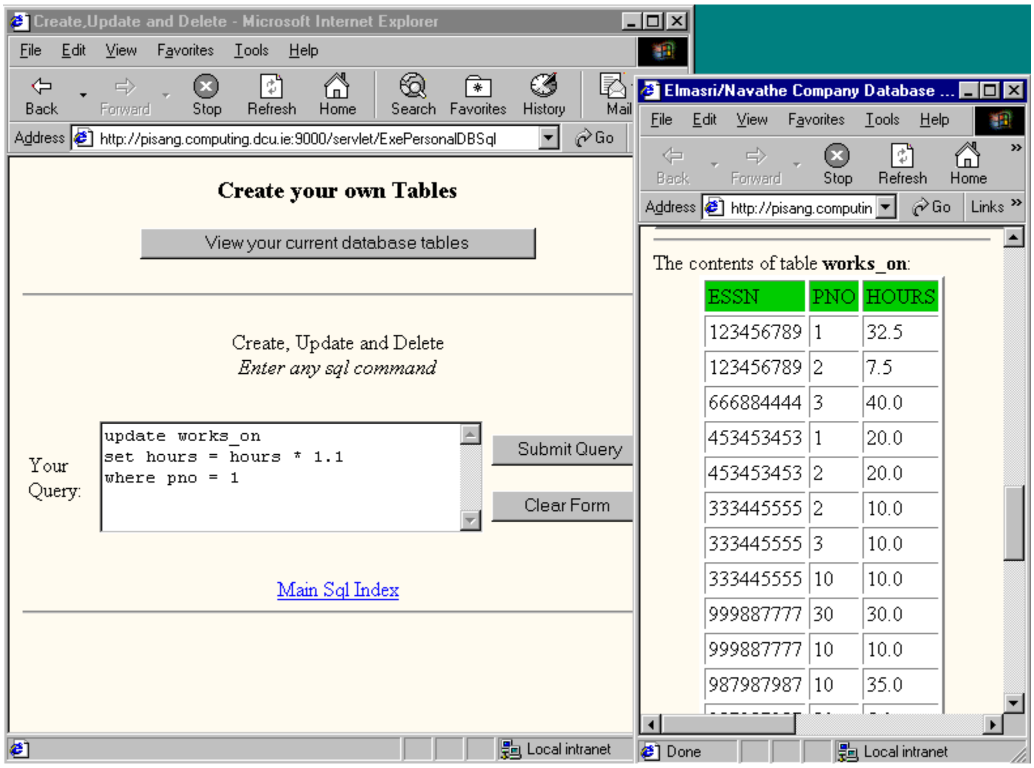

Figure 4. Interactive lab – SQL definition, update, and query.

Learning Behaviour Analysis

Whether students actually use a learning and training environment in the way expected by the instructor is often an open question. Behaviour analysis is therefore important. Surveys alone can often be inaccurate in this respect. Therefore, we proposed a novel type of analysis method, based on Web usage mining techniques combined with classical survey techniques. We will explain this method in more detail before summarising the analysis results.

Methods and Techniques

Learning behaviour and the organisation of learning processes is not sufficiently understood. The analysis of the students' learning behaviour is therefore important. Student behaviour in tool-mediated environments is determined by the students' motivation, their acceptance of pedagogical approach and technical environment, their learning organisation, and their activities in the environment (i.e. their usage of the tool).

The behaviour of students in computer-based teaching and learning environments is influenced by the motivation to use the system and the acceptance of the approach.

- Motivation – the reason to do something – causes learners to act in some planned and organised way, giving the activities a purpose.
- Acceptance – to follow the learning approach and use the system willingly – is crucial for the introduction of new educational technology.

We distinguish two aspects of a student's concrete behaviour, which defines the learning activity. Firstly, the learning organisation addresses the study habits and captures how students organise their studies over a longer period of time. Secondly, the usage of the system captures single learning activities and embraces how students work with the system in a single study session.

- Organisation – the way activities are planned and put into logical order – reflects study habits, is guided by purpose.
- Usage – the way the system is used – reflects the actual learning activities of learners.

The instruments for the behaviour analysis include survey methods to address motivation and acceptance and Web usage mining techniques (Pahl, 2004) to capture organisation and usage in a Web environment. This combination of methods provides a more complete and accurate picture than uses of survey and student observation (Kinshuk, Patel, & Russell, 2000) or student tracking features available in various teaching and learning platforms (Coates & Humphries, 2001).

Web mining is a technology that discovers and extracts knowledge from structured Web data – usually server access logs that record page requests from a Web browser in a Web environment. A Web log record contains a user and/or machine ID, the time of the request, and the requested document. All Web-based systems where the activity is controlled at the server side produce data suitable for this kind of analysis.

Results

We have applied the analysis technique over a period of two years (both surveys and Web usage mining).

- Motivation. There is a very clear preference for coursework preparation as the main motivation. A Web log analysis shows that the SQL tutorial is mainly (two thirds of sessions) used to support coursework during term and to a lesser extent (one third of sessions) for exam preparation, which confirms the survey result. More insight into the motivation of the student's study organisation comes from a question regarding the main values of a virtual system – 'always available' and 'self-paced learning' are seen as the key advantages.
- Acceptance. Students have indicated an overall acceptance of tool-mediated active learning as the pedagogical approach. Comparing traditional and virtual tutorials gives a more differentiated view on acceptance. No favourite emerges; this clearly demonstrates that students accept virtual tutorials as equally suitable and effective. We have asked the students about their preference of delivery mode with respect to performance in exams. Again, virtual tutorials are considered to be at least as good as traditional ones as a means to support good coursework and exam performance. Another indicator for the acceptance of the approach of self-directed active learning is reflected by frequent and regular usage of the system. While Web mining shows that the tutorial system has not been used frequently and regularly over the whole term, it has however been used intensively in certain periods to fulfil a particular purpose.
- Organisation. The study organisation – the self-paced learning aspect – shows a just-in-time learning approach of students with high usage immediately before coursework deadlines during term and end-of-semester examinations. Web usage mining can give us a clearer picture about the organisation. Session classification allows us to determine the purpose of learning sessions, for instance, attending virtual lectures or practising in

virtual tutorials, and to compare the session purposes of different periods. Surprising is the high number of organisational visits – even though these visits tend to be much shorter than tutorial sessions. Time-series analyses of session classifications allow us to monitor the changing focus. Interactive services are heavily used during term, but less so for the exam preparation.
- Usage. Besides the long-term study organisation, analysing learning activities within a study session is crucial in order to understand how students learn. An abstract picture of the purpose(s) of each session is provided by the session classification, but we also need to look in detail how students interact with the system, whether they repeat units, or whether they combine interactive elements with lectures. A pattern analysis can answer these questions. Students recognise the potential of virtual courses to use tutorial and lecture features at the same time, overcoming time and space constraints that apply to a traditional delivery. 84.1% of all student sessions follow a pattern of mixing active tutorial learning and lecture look up. While nearly all students avail themselves of this feature in their first tutorial sessions, we observed a decrease of lecture lookup over time, indicating the increased self-reliance of students.

Effectiveness Evaluation

Behaviour analysis is an essential instrument for effectiveness evaluations of tool-mediated active learning. However, effectiveness also comprises aspects such as an overall positive learning experience and in particular student attainment. Exam and coursework results – in comparison with a traditional delivery – can prove the effectiveness with respect to attainment, (Smeaton & Keogh, 1999). In our system, the student attainment level of the traditional delivery has always been reached since the virtual tutorial was introduced in 1999. We found a minimal correlation between usage and attainment for the SQL tutorial system. Frequent and extensive usage in general pays off in terms of good coursework and exam results. This can be interpreted as an indication for the benefit of using the interactive tutorial for exam preparation and coursework. In contrast to virtual lecture attendance, where books can serve as an alternative, interactive tools to acquire programming skills are more difficult to replace and, therefore, their usage is beneficial.

Discussion

Tool-mediated active learning is suitable for skills-oriented subjects such as some computer science topics. We have investigated an integrated SQL training feature for a database course, which implements pedagogical ideas based on active learning and realistic settings. Our main observation is that these types of feature need to exhibit two types of properties:

- Interactivity. Interactivity of the features will enable active learning.
- Integratedness. Only an integration with other features can create a realistic, meaningful learning context.

Ravenscroft, Tait, and Hughes (1998) stress the importance of the appropriate level of student interaction with learning content. Classical text-based and editable material for online lectures has been more successful than animations, since students can interact with text through annotation by personal remarks. Often, however, a distinction is made between content aimed at developing conceptual knowledge on one hand and skills development on the other (Weston & Barker, 2001). The students' motivation in our case is the acquisition of skills and good performance in practical coursework and examinations. Consequently, the form of interaction with course material supporting active learning of skills is different from knowledge-based learning. Our conclusion – that the right level of interaction has to be designed and supported – is the same.

Besides interactivity, integration is another essential aspect. We can describe integration in two dimensions:

- Horizontal. Horizontal integration refers to the integration of features addressing conceptual knowledge, procedural knowledge, and skills for the same topic. Our SQL feature with its four parts is an example.
- Vertical. Vertical integration refers to the integration of features for a particular learning goal (knowledge or skills) for different topics. An example is the lab integration providing an integrated modelling, programming, and analysis environment for database development.

Our SQL feature is currently used in a blended learning scenario with both independent and supervised learning. The more independent learning is aimed at, the more the tool needs to replace the instructor and needs to emulate functions of lab tutors for the more practical elements. In this case more synchronous automated feedback and guidance is required. This setting should ideally make use of personalisation, i.e. adapt to the circumstances of the individual learner (Kenny & Pahl, 2005).

We have addressed behaviour analysis in more detail here. This was motivated by the need to understand learner behaviour in these novel types of learning environments to optimise instructional design and to adapt these environments to changing learning behaviour. Behaviour analysis, however, is also an integral part of an effectiveness evaluation. Surveys alone cannot provide the necessary information. Non-intrusive, observation-based techniques are required. Web usage mining is such a technique that is based on the activitiy traces left by users of Web-based systems. In relation to our SQL features, we looked at learner behaviour (motivation, acceptance, organisation, usage) and performance here. We have applied a formative evaluation to investigate the issues mentioned above – unknown and changing learner behaviour.

References

[1] Coates, D. & Humphreys, B.R. (2001). Evaluation of Computer-Assisted Instruction in Principles of Economics. *Educational Technology & Society* 4(2).

[2] Grabinger, R.S. (1996) Rich environments for active learning. In D. H. Jonassen (ed): Handbook of research for educational communications and technology. New York: Macmillan.

[3] Guzdial, M. and Kehoe, C. (1998) Apprenticeship-based learning environments: A principled approach to providing software-realized scaffolding through hypermedia. *Journal of Interactive Learning Research*, 9(3/4), 289-336.

[4] Kenny, C. & Pahl, C. (2005) An automated tutor for a training environment for database programming. *SIGCSE Symposium, St. Louis, USA.*. (accepted)

[5] Kinshuk, Patel, A. & Russell, D. (2000). A Multi-institutional Evaluation of Intelligent Tutoring Tools in Numeric Disciplines. *Educational Technology & Science* 3(4).

[6] Murray, S., Ryan, J., & Pahl, C. (2003). A Tool-mediated Cognitive Apprenticeship Approach for a Computer Engineering Course. *International Conference on Advanced Learning Technologies ICALT'2003*, pages 2-6. IEEE.

[7] Nardi, B. (ed.) (1997). *Educational Context and Consciousness: Activity Theory and Human-Computer Interaction*. MIT Press.

[8] Pahl, C. (2002). An Evaluation of Scaffolding for Virtual Interactive Tutorials. *Proc. 7th E-Learn 2002 Conference*, Montreal, Canada. AACE.

[9] Pahl, C. (2004). Data Mining Technology for the Evaluation of Learning Content Interaction. *International Journal on E-Learning IJEL*. AACE.

[10] Pahl, C., Barrett, R., & Kenny, C. (2004). Supporting Active Database Learning and Training through Interactive Multimedia. *International Conference on Innovation and Technology in Computer Science Education ITiCSE'04*. Leeds, United Kingdom. ACM.

[11] Ravenscroft, A., Tait, K., and Hughes, I. (1998) Beyond the Media: Knowledge Level Interaction and Guided Integration for CBL Systems. *Computers & Education*, 30(1/2):49-56.

[12] Smeaton, A. F. & Keogh, G. (1999). An Analysis of the Use of Virtual Delivery of Undergraduate Lectures. *Computers & Education,* 32(1), 83-94.

[13] Stanberry, A.M. (2000). Modifying the Teaching/Learning Process in an Interactive Video Network: A Systemic Analysis Approach. *Online Journal of Distance Learning Administration,* 3(4).

[14] Weston, T.J. and Barker, L. (2001). Designing, Implementing, and Evaluating Web-Based Learning Modules for University Students. *Educational Technology*, 41(4):15-22.

[15] Xu, L., Pahl, C., & Donnellan, D. (2003). An evaluation Technique for Content Interaction in Web-based Teaching and Learning Environments. In Proceedings International Conference on Advanced Learning Technologies ICALT 2003. IEEE.