Supporting Active Database Learning and Training through Interactive Multimedia

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ABSTRACT

The learning objectives of a database course include aspects from conceptual and theoretical knowledge to practical development and implementation skills. We present an interactive educational multimedia system based on the virtual apprenticeship model for the knowledge- and skills-oriented Web-based education of database course students. Combining knowledge learning and skills training in an integrated environment is a central aspect of our system. We show that tool-mediated independent learning and training in an authentic setting is an alternative to traditional classroom-based approaches.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education – *Computer-assisted instruction (CAI).*

General Terms

Management, Design, Human Factors, Languages.

Keywords

Database courseware, virtual apprenticeship theory, multimedia, tool-mediated independent learning, knowledge and skills.

1. MOTIVATION

The central objective of a database course is often to enable a learner to successfully carry out a substantial database development project. Database development is an activity that requires the understanding of central concepts and theories, but also the acquisition of skills. This is a property that the database subject shares with other engineering subjects. Classical learning has to be complemented with training activities. Modelling and programming activities – central in database development – are best supported in a learning environment through a learning-by-doing approach. We present a courseware system – IDLE (the Interactive Database Learning Environment) – that we have used for several years to support a database module in an undergraduate computing degree at our university.

Providing a learner with the necessary knowledge, skills, and experience is usually difficult to achieve. It becomes a challenge if online media are to be used as the central teaching and learning infrastructure. Our solution to this problem is based on a pedagogic model called the virtual apprenticeship approach [4]. In an apprenticeship the apprentice learns under the guidance of a master to become self-reliant in the subject and to master given tasks, such as a database project, on her/his own [1]. In the virtual world the master is replaced by a tutor tool that mediates between learner and content and that supports the independent learner in becoming self-reliant. An authentic setting for the activities is central for the success [2].

The technical side of our solution provides a Web-based multimedia system that focuses on the integration of different interactions and the mediation between learner and content. Knowledge and skills require different educational approaches and, consequently, different media and media interactions.

Our hypothesis is that virtual active learning and training in an authentic setting is possible for skills-oriented subjects. Our evaluations show that an educational multimedia system supporting the autonomous learner can result in a high quality learning experience. Different media can support different aspects of the learning process. The Web offers new ways for the learner to interact with educational media. Of particular importance for the effectiveness of the approach are form and level of student interactions with educational media (which provide access to knowledge and skills-oriented activities).

2. DATABASE DEVELOPMENT

Database development requires an understanding of central database technology concepts but also skills in modelling and programming. A central teaching goal of our database course is to enable learners to master a database development project. For this presentation we introduce a simplified development process – which we use to discuss the requirements for a supporting educational multimedia system and our solution to the problem.

The database development process shall consist of two major stages: *design* and *implementation*. *Design* focuses on modelling structural aspects of database applications:

- Required knowledge: the learner needs to understand data models and data modelling principles.
- Required skills: the learner needs to be able to model applications using a graphical notation.

Implementation focuses on, firstly, the creation of structural elements (database tables) and, secondly, the implementation of application-specific manipulation operations (updates, queries):

- Required knowledge: the learner needs to understand, firstly, data modelling for structural aspects and, secondly, an operator algebra for manipulation and retrieval aspects.
- Required skills: the learner needs to be able to, firstly, structurally model applications using a textual notation and, secondly, to programmatically manipulate the database.

3. IDLE – AN INTERACTIVE DATABASE LEARNING ENVIRONMENT

IDLE – the Interactive Database Learning Environment – is a Web-based system that supports a learner in acquiring knowledge and skills to carry out database development projects.

3.1 Educational Foundations

Knowledge can occur in two forms: declarative (facts) and procedural (instructions). In addition to knowledge, skills have to be acquired by learners in our course.

- *Declarative knowledge* is often provided in lectures – comprising theories, models, and concepts that are essential for the understanding of databases and their development.
- *Procedural knowledge*, in particular in relation to database system functionality, is often provided in tutorials through animations of system processing functions. Understanding the reaction of systems to user input is essential.
- *Skills* are required by the learner to provide quality input to a database development system.

The IDLE system focuses on the interaction between learner and content [5]. Neglecting learner-learner and learner-instructor interactions it supports the autonomous, independent learner.

We see the learner as a *virtual apprentice* for database engineering. The acquisition of knowledge and skills via the construction of artefacts in the apprenticeship is essential. An authentic setting and the possibility to produce and manipulate the 'real thing' are central success factors to support constructive procedural knowledge and skills acquisition. Understanding databases and their development is a consequence of this process of constructing database systems. The *apprenticeship theory* [1] involves other educational theories and techniques. *Scaffolding* is a support technique that can substitute the master of the apprenticeship model in the virtual world [4]. *Activity theory* explains the principle of tool mediation in an online environment – here multimedia tools handle the student's interaction with the course content. A *constructivist style* of education shall be facilitated, allowing the student to construct knowledge and obtain experience through active participation in the course.

3.2 Technical Foundations

Interactive educational multimedia is the technical platform to implement knowledge- and skills-oriented learning. The design of multimedia features needs to take the specific requirements of interaction in the educational context into account.

- Knowledge representation can go beyond text as the main medium. We use data and process visualisation and animation techniques to support lectures and tutorials [3].
- Skills acquisition support requires the implementation of a different level of interaction between learner and content. In order to enable learning-by-doing in an active learning approach, the learner should be able to interact with the system in terms of activities relevant for a development project – an authentic setting is therefore a prerequisite.

3.3 Implementation

IDLE consists of a number of educational services – lectures, tutorials, labs, self-assessment, a resources centre, and an administration part. We will focus on the first three services. *Lectures* support the acquisition of declarative, foundational knowledge (theories, models, concepts). Media types are text and audio. *Tutorials* support procedural knowledge acquisition through visualisation. The media type is animation. *Labs* support activities for skills acquisition using interactive media types.

Each service supports different database topics. The services are implemented through a number of individual *educational components* that support learning and project development:

- An audio-based *lecture system* providing background and foundations for *all project stages.*
- At the *design stage* an *Entity-Relationship modelling tutorial* and an *Entity-Relationship editor* (a lab component) – see Figure 1.
- At the *implementation stage* a *relational data model and algebra tutorial* and an *SQL processor* (a lab component) – see Figure 2.

The integration of these components in the environment is central to allow a learner to learn, train, and develop within the same environment. In order to support project development, a workspace component provides facilities for the learner to store intermediate and final artefacts produced during the process.

4. A SAMPLE DEVELOPMENT SESSION

We illustrate the use of the IDLE system by a walkthrough of a development project session, carried out by a reasonably mature learner only occasionally in need of background learning. (The traditional learning approach for a novice is also supported in the environment.)

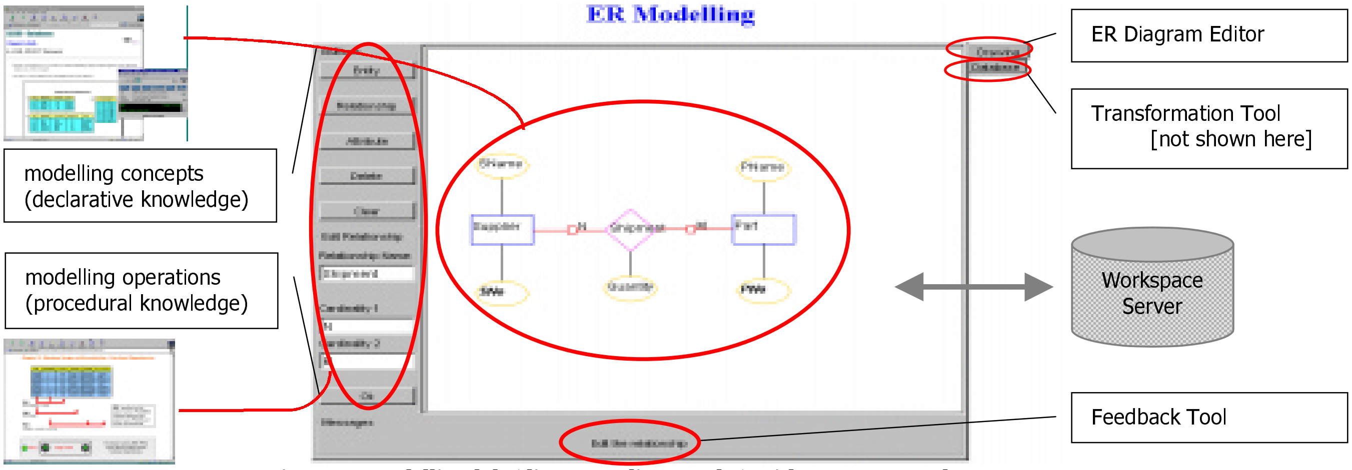

Figure 1. Modelling lab (diagram editor applet) with access to workspace server.

The simplified process model for a development project involves two stages – see Section 2. The first is the design stage and has the production of a structural model using an Entity-Relationship diagram as the objective. The second is the implementation stage and has the production of two artefacts as the objective. Firstly, a structural database implementation (stored tables) shall be defined, and, secondly, manipulation operations (stored updates and queries) shall be implemented.

4.1 Design Stage

Assuming that the learner – the virtual apprentice in our model – has already acquired some data modelling knowledge and skills, he/she can use the Entity-Relationship (ER) editor straightaway

- to create an ER diagram (see Figure 1), supported by the graphical features of the tool, which guide her/him to create a syntactically correct and sensible model, and
- to transform the diagram into a relational data model representation (SQL) and store this SQL representation in a workspace area provided by an underlying database server.

The integration with other features is achieved via a workspace server. Other learning material is still available.

4.2 Implementation Stage

Two aspects need to be addressed at this stage: *structural definitions* and *manipulation operations. Structural definitions* (database table definitions) are already done if the ER model was complete and has been transformed using the ER-transformation tool. *Manipulation operations* comprise SQL updates and queries (Figure 2). Here we assume that the learner lacks knowledge and skills to perform the required project tasks.

- He/she would do the relational algebra tutorials to understand how a database management system executes queries – understanding the system side, i.e. how the system reacts to user input, is an essential learning objective.
- He/she would then use the SQL interface to write and execute (i.e. define and test) SQL queries. This practical part starts with a guided tour through some simple problems. The SQL processor interface contains two areas. The *execution part* – representing the training aspect – allows the learner to execute project-related queries. The *scaffolding part* – representing the master – provides advice, feedback, and context links.

Advice and feedback are central scaffolding features for tool-mediated learner-content interaction. An *advice* section captures, in textual form, learning problems that the instructors of this course have encountered over the years. *Feedback* is provided for student input. We distinguish several levels. Firstly, syntactical errors in the learner input are captured and explained in detail. The system also looks at semantical problems. For features where the solution is known to the system, the feedback tool analyses the input and gives hints or partial solutions in order to allow the learner to solve a problem. The tool also tracks the user activities and can, on request, suggest a collection of targeted exercises to overcome a particular problem.

IDLE is designed as an independent learning tool where a virtual master (advice and feedback) replaces the instructor. This type of support is necessary to guide and support the learner in reflection processes. The overall objective of the apprenticeship model is to support learning and training in an authentic setting, i.e. to combine learning features (lectures and tutorials) with features of a realistic database development environment (lab components). It aims at allowing the learner to train, but also to learn about concepts and theories through active participation in authentic features. The system allows the learner to become self-reliant and take ownership in the learning process.

5. EVALUATION

The *effectiveness* and *success* of the virtual apprenticeship approach and the IDLE system depends on a number of *criteria*: a positive *learning experience* for the learner, an improved *learner performance* benefiting both learner and instructor, and cost-effective *instructional design* for the instructor. We address these criteria addressing opinion, performance, and behaviour, respectively, in the following sections.

5.1 Student Opinion

Student attitude and opinion are important evaluation aspects. We addressed the acceptance of the approach in general and asked the students to compare the virtual apprenticeship with traditional classroom-based learning.

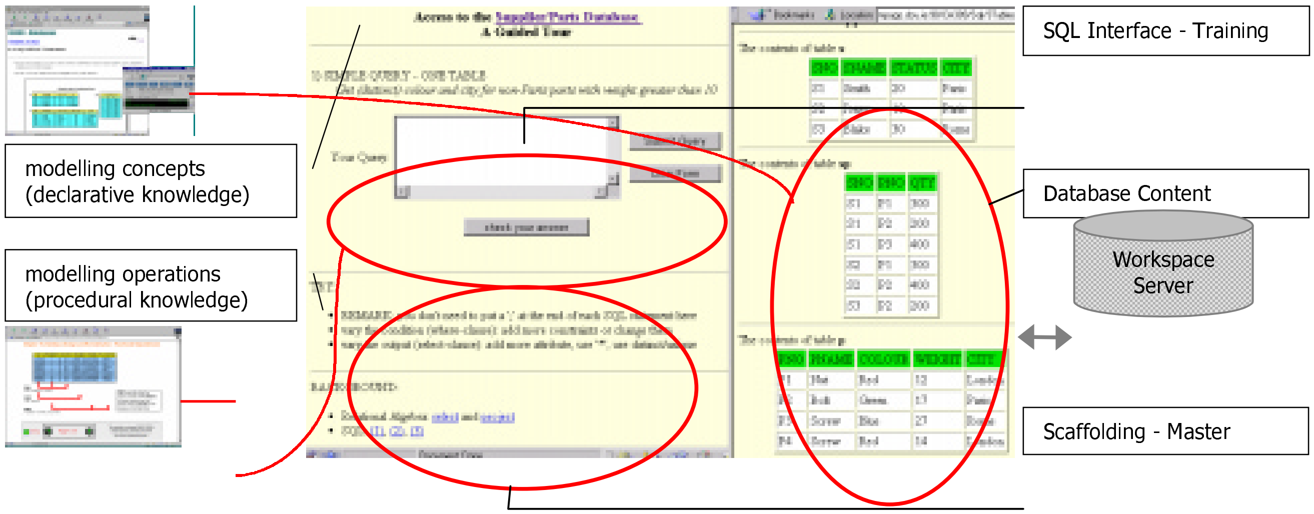

Figure 2. SQL programming lab (HTML forms interacting with remote database server).

- Our surveys showed a strong overall acceptance of tool-mediated apprenticeship learning as the approach. More than 85% of the students appreciate online teaching and learning as part of an on-campus degree programme. Constant availability and self-paced learning are seen as the main advantages of this type of delivery.
- Comparing traditional and virtual labs can give a more differentiated view on acceptance. No clear favourite emerged, which clearly demonstrates that students accept virtual tutorials and labs as equally suitable and effective.
- We asked the students about their preference of delivery mode with respect to performance in exams. The opinion was split. Again, this result shows that virtual learning features are accepted by students as at least as good as traditional ones in supporting one of their major objectives, i.e. good coursework and exam performance.

5.2 Student Performance

Besides student opinion capturing the learning experience, the learners' performance in exams and other forms of assessment is an important effectiveness criterion. Improving coursework and exam results is a goal shared by both learner and instructor.

Since 1999 we have enhanced and extended our interactive features on a regular basis. Over the same period we have observed a constant improvement of exam and coursework results by a few percent each year. This result improvement can be attributed to the system improvement. We have compared these results to attainment results of a comparable group that was taught in a traditional style. During the past two years we have exceeded the traditional style performance results.

5.3 Learning Behaviour

Virtual courseware systems require a considerable initial investment. Developing instructional designs and infrastructures in a context that is still not well explored requires nonetheless a good understanding of learner behaviour. To overcome this problem constant learner behaviour evaluation is necessary.

We analysed the students' interaction with the educational media and how different features have been combined – information that for instance shows how self-reliant students have become. Behaviour analysis allowed us to address the efficiency of learning within the constraints of the educational model.

Combining different educational features is required to learn to develop a database application. The different features offer different perspectives on the same topic, e.g. relational algebra can be presented through the mathematical properties, but also as an interactive interface to execute relational algebra expressions. Understanding how students learn with these features is essential to support the learning processes in the most optimal way.

We have used Web usage mining to extract behavioural patterns from access logs created by Web servers and tools in IDLE [6].

- *Integrated use of features*: The results show that 84% of all learning sessions actually follow a pattern of mixing active learning and training features and scaffolding at the same time. Usage mining confirms that in 77% of all training sessions students have accessed background material.
- *Scaffolding*: The absolute numbers of scaffold requests have been reduced to 35% in the later sessions compared to the first. This process – called fading – shows the increasing self-reliance and thus the effectiveness of this concept. The system can provide the necessary coaching to a large extent.
- *Behaviour change*: Changes in behaviour are often an important element in the learning process. One example is the fading use of scaffolds that is expected to happen in an effective scaffolding implementation. Another example is that towards the end of term students combine features more often, i.e. they have learned to work with the new medium.

5.4 Discussion of Evaluation Results

From the learner's point of view the effectiveness of the virtual apprenticeship model can be analysed in terms of two measurable criteria: exam/coursework performance and the ability to carry out projects independently and successfully. Exams and other performance data are therefore essential, but also student opinion and learning behaviour contribute valuable information to the overall evaluation.

Our experience shows that a virtual apprenticeship approach is feasible. Students accept the approach – expressed through their behaviour (meaningful usage of database development features) and opinion (appreciation of feature implementations based on the apprenticeship theory). The authentic setting played an important role – allowing learners to practice and train in an environment that resembles the real-world scenario. Theories such as scaffolding were successfully implemented. The student performance has improved steadily over the past years as a result of incremental system improvements (partly the improvements were motivated by evaluation results). The system supports more than learning-by-doing. By carrying out a comprehensive project within the system, a deeper understanding of the problems of database engineering can be achieved.

6. CONCLUSIONS

Addressing knowledge and skills acquisition in an online learning and training environment requires an approach different from the provision of lecture material online only. We have based our solution on the virtual apprenticeship model [4], which addresses tool-mediated, coached learning and training of autonomous learners in an authentic setting.

The Web has so far mostly been used to provide access to resources and to support a usually passive style of learning. With our system, we have demonstrated that skills-oriented active learning in a constructivist style is possible in this environment. Tutorial, lab, and even real development activities can be facilitated through Web technologies. Since the subject of our course is computing, we can even provide an authentic setting and allow learners to carry out project work within the course environment. Our evaluations have shown that online learning in this context does not need to entail a loss of quality in the learning experience and the effectiveness of the learning process.

Computing is a subject that is ideally supported by a virtual authentic learning approach. Skills training is an integral component of many computer science or engineering courses. Machine-processable input is often a part of the learning and in particular training activities. Authentic features such development environments can – with relative ease – be incorporated into learning and training environments. We have demonstrated how a variety of activities from graphical design, theoretical components and language processing to simulations and animations can be facilitated through interactive educational multimedia technology. Independent learning can be supported by these environments; even collaborative learning could be supported if the workspaces architecture would be extended into a shared version and communication features would be included.

Comparing the training of database application developers in a traditional and in a virtual environment we can observe differences, but also similarities.

- Virtual environments are, and should be, different. Physical and time-related constraints and boundaries that apply to the traditional environment do not exist. This should enable a more integrated and active style of asynchronous learning, allowing a self-paced and self-reliant style of learning.
- Virtual environments should, and can be, similar. No direct access to instructors and peers does not necessarily result in inferior learning outcomes. A master or instructor can be replaced through tool-mediated feedback and guidance.

A key to making virtual learning and training a competitor to the traditional form is to address the appropriate level of student interaction with educational or knowledge media [7]. Often a distinction is made between educational content aimed at developing conceptual knowledge, problem solving and analytical skills on one hand, and skills development, recognition, and memorisation on the other [8]. The students' motivation in our case is the acquisition of skills, rather than knowledge. Consequently, the form of interaction with course material supporting active learning or training of skills, as expressed by the virtual apprenticeship model, is different from purely knowledge-based learning. Learning by doing in an authentic setting allows students to adequately interact with skills-oriented educational media.

7. ACKNOWLEDGMENTS

Our work was supported by the Dublin City University Teaching and Learning Fund DCU-TLF and the Irish Research Council for Science, Engineering and Technology IRCSET.

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