Tretiakov A., Kinshuk & Tretiakov T. (2003). Designing Multimedia Support for Situated Learning. In V. Devedzic, J. M. Spector, D. G. Sampson & Kinshuk (Eds.) *The 3rd IEEE International Conference on Advanced Learning Technologies Conference Proceedings*, Los Alamitos, USA: IEEE Computer Society, 32-36 (ISBN 0-7695-1967-9)

Designing Multimedia Support for Situated Learning

Alexei Tretiakov and Kinshuk

Department of Information Systems, College of Business, Massey University, New Zealand

Takako Tretiakov

Department of Commerce, Hutt Valley High School, Lower Hutt, New Zealand

Abstract

Situated learning is known to be an effective didactic approach, yet, multimedia systems with built-in support for it are uncommon. We analyze the domain-independent requirements for such a system, formulate a high-level architecture, apply it for the domains strongly relying on the use of mathematical formulae involving dimensioned quantities, and implement a proof-of-concept prototype. The results of our work will be of benefit for the future development of multimedia systems supporting situated learning.

1. Introduction

Over a number of years, there has been a sustained interest in situated learning, which was found to be particularly relevant to technology-based learning [1 - 7]. Here, we suggest a high-level architecture for a multimedia system supporting situated learning, and illustrate it for the domains strongly relying on the use of mathematical formulae involving dimensioned quantities.

The rest of the article is organized as follows: after introducing situated learning theory and the teaching approaches based on it, we describe the architecture, it's application, and a proof of concept prototype implementation.

2. Situated Learning

The theory of situated (or situational) learning emerged as an application of the constructivist epistemology to the learning process. It explains cognition, including problem solving, sense making, understanding, transfer of learning, creativity, etc., in terms of the on-going interaction between the learners and the environments to which they are exposed [3]. Rather than being a static symbolic representation, "stored" in the brain of an individual, knowledge is situated, being a product of the activity, context, and culture in which it is developed and used [1]. A classical example of situated learning is language learning [8]. Children are able to learn a language at an incredible speed when they are actively participating in an environment where the language is spoken. On the other hand, classical teaching methods involving memorization of symbolic information such as vocabulary and grammar rules is known to have a very modest success rate. The claim of the situated learning theory is that all learning is similar to language learning, with knowledge being constantly constructed and re-negotiated by its practitioners (such as language speakers) [1]. Learning occurs via the exposure to and participation in an environment in which the knowledge is practiced.

Two mutually complementary didactic approaches have been developed as applications of situated learning theory in teaching practice: anchored instruction and cognitive apprenticeship.

Anchored instruction is based on the following principles [9, 10, 11]:

1. Learning and teaching activities should be designed around an "anchor" which should be some sort of case-study or problem situation.
2. Curriculum materials should allow exploration by the learner.

Anchor provides the context in which the learners are situated, while explorable materials allows students to play an active role, and thus to construct rather than to passively accept knowledge. Anchored instruction is particularly relevant as a paradigm for technology-based learning [10], as computers provide the means to both render context and to offer exploration tools.

Cognitive apprenticeship relies on social aspects of situational learning and as such spells out the role of the teacher as a facilitator of learning. In cognitive apprenticeship, learning occurs while learners are working on tasks that are slightly more difficult than they can manage independently (zone of proximal development), requiring the aid of their peers and instructor to succeed [12 - 15]:

1. Teacher provides a model for a problem solution by solving a similar problem in front of the students.
2. Teacher provides scaffolding by offering hints as students are working on a problem.
3. Teacher fades by gradually removing scaffolding as students become more proficient at solving certain type of problems.

Tretiakov A., Kinshuk & Tretiakov T. (2003). Designing Multimedia Support for Situated Learning. In V. Devedzic, J. M. Spector, D. G. Sampson & Kinshuk (Eds.) *The 3rd IEEE International Conference on Advanced Learning Technologies Conference Proceedings*, Los Alamitos, USA: IEEE Computer Society, 32-36 (ISBN 0-7695-1967-9)

To complete our outline of situated learning approaches we need to mention the need for multiple representations of the concepts being learned, to improve their transferability between contexts [16, 17]. Multiple representation approach suggests exposing a concept from a variety of points of view.

3. An architecture for the support of situational learning

Here we suggest a simple architecture for the support of situated learning, including the elements of both anchored instruction and cognitive apprenticeship. Although there are a number of publications describing systems for situational learning [18 - 20], the systems involved tend to be highly specialized and/or rely on the use of expensive resources, such as virtual reality or greatly increased teacher participation. We attempt to find an approach that would be:

1. general enough to cover a wide range of systems;
2. offer an option to design systems that are inexpensive to implement and to operate.

The architecture is outlined in Figure 1.

Story creates the context for the whole course. Its primary role is to situate the learners in the course domain by demonstrating its relevance to their goals and aspirations, giving examples of real-world situations, providing historical perspective and projections into the future etc. Story may also include model solutions for dealing with common problems and for conducting other types of activities. Thus, story plays a role similar to the role of anchors in [9, 11].

While story is a good place to take advantage of multimedia features such as video, sound, images and diagrams, we believe that it is possible to write very effective stories by using text only. Generally, story does not "cover" the domain knowledge in a formal and comprehensive manner. Rather, it is for as much as possible an "easy reading", light and informal. On the other hand, "legacy" instructivist materials can be reused as part of the story, hence, rather than promoting a purely constructivist approach we envisage a range of possibilities.

Activities are related to the story and can be performed by the learners as they are exposed to the story (e.g., they can be implemented as hyperlinks). An activity prompts the learners' participation by requesting them to perform certain actions and to make certain decisions within the course domain. An important criterion for an activity is that it should be possible to tell whether the outcome was successful or not (or, rather, to which degree the outcome was successful). Activities should be formulated to provide further, more specific anchoring: in terms of dealing with "real world" issues rather than in terms of operating symbolic representations. The most common type of activity is a problem, for which there is a correct answer or a criterion allowing to determine if a specific answer is correct. If assessment in the form of exams and tests is used in the course, activities used in the assessment should be similar to the activities used in the course, and students should be aware of it.

For activities, scaffolding and fading are to be provided by giving tree levels of feedback (which can be implemented as hyperlinks):

1. Success criterion. A problem answer or some other way to determine to which degree the learner's performance was successful. Success criterion provides very little if any pointers as to how to perform the activity, so learners accessing it retain an "open mind" as to trying their own approaches.
2. Hints. Some indications at how a solution could be achieved, stopping short of revealing the solution.
3. Possible solution. A model answer provided by an expert participant in the domain's community of practice.

The three levels of feedback implement both scaffolding and fading, as we expect the students to try and complete activities at the lowest level of feedback possible (which can, but does not necessarily have to be enforced by tracking navigation and assigning points depending on the level of feedback at which the problems are being solved).

For learners, an activity together with a successful solution is a representation of the domain knowledge. Activities should be chosen to expose the domain from a variety of points of view, thus achieving multiple representations.

Finally, the toolbox offers students the tools necessary to experiment with the domain concepts. The most important role of the toolbox is to provide access to comprehensive and systematic coverage of information relating to the domain (effectively, an "instructivist" view of the domain). It should be stressed, that the intent is not to familiarize students with the toolbox content, but to support them in successfully accomplishing the course activities. The toolbox may also include tools such as special purpose calculators, visualization facilities etc.

The toolbox is accessible via hyperlinks from the story, activities' descriptions and activities' hints and answers. It also can (but does not have to) offer a separate interface allowing to access and to explore the toolbox capabilities directly.

One aspect of situational learning that is (by design) not supported by the architecture is communication between

Tretiakov A., Kinshuk & Tretiakov T. (2003). Designing Multimedia Support for Situated Learning. In V. Devedzic, J. M. Spector, D. G. Sampson & Kinshuk (Eds.) *The 3rd IEEE International Conference on Advanced Learning Technologies Conference Proceedings*, Los Alamitos, USA: IEEE Computer Society, 32-36 (ISBN 0-7695-1967-9)

learners and between learners and teachers. While we assume that communication happens as students are exposed to the story, and, at higher intensity, as students are working through the activities, we believe that communication is best achieved "out of band", by using the facilities most appropriate for a particular situation (and the ones already familiar and in use). Hence, communication can be achieved via classroom discussions or students meeting outside the classroom, as well as via email, email lists, discussion groups, instant messaging etc (see [21] for an evaluation of the use of technology for learner/learner and learner/teacher communications in a project-based Computer Science course). We believe that this aspect of situated learning is orthogonal to the architecture suggested. An alternative approach, such as the one taken in [22], would attempt to impose communication tools on the participants, with the risk of the tools being circumvented and left unused. On the other hand, our architecture attempts to provide a maximal level support possible at the level of student-system interaction, to minimize the necessity of communication between students and teachers and thus to allow scalability to classes with large numbers of students.

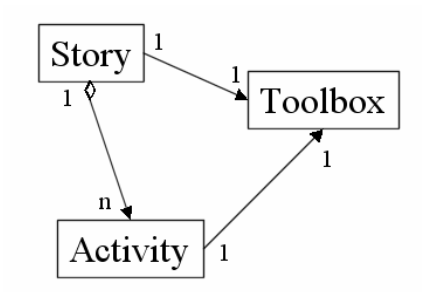


Figure 1. An architecture for situated learning support

4. Navigational structure for on-line content with mathematical formulae

In case of teaching in a domain heavily relying on mathematical equations involving dimensioned quantities, much of the cognitive overhead imposed on learners is connected with the necessity to memorize the meaning of variables, their units, and relationships between equations. Domains of this kind are very common and include areas of study such as physics, engineering, physical chemistry and biophysics, accountancy, etc. Reliance of variables and equations as tools suggests that handling variables and equations should be supported by the toolbox.

The rest of the article outlines the possible organization of the toolbox to support the work with dimensioned variables.

Variables and equations necessary to be active in a certain domain are related to each other. It is reasonable to assume that in the domains of interest many of the activities are likely to be formulated as problems that can only be solved by using certain variables and equations as tools. Learners are likely to benefit if the relationships are exposed as navigation structure.

The rest of this section explores the entities and relationships involved and the navigation structure they suggest in some detail. A proof of concept implementation (in the domain of fluid mechanics) is referred to as an illustration.

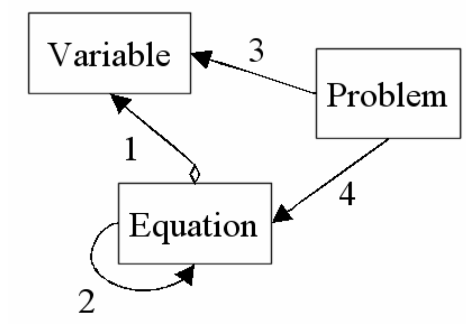


Figure 2. Navigation diagram

A variable is characterized by the symbol that represents it, a short textual description and by its dimensionality.

An equation is characterized by its visual representation. An equation is atomic, in a sense that we do not parse it.

An equation is explicitly associated with the relevant variables by the course author, based on educational considerations (association 1 in Fig 2). We expect that in the overwhelming majority of cases an equation will be associated with a subset of variables that actually occur in it, but the system does not enforce it in any way. The cardinality of association between equations and variables is many-to-many, a variable can be related to multiple equations, while an equation can be related to multiple variables.

An equation is explicitly associated by the course author with other equations that can be used to derive it or can serve to clarify it, based on educational consideration (association 2 in Fig 2). The system does not verify that the association is correct. The cardinality of association between equations is many-to-many, an equation can be clarified by multiple equations, and can clarify multiple equations.

We expect that most authors would try to avoid cycles (e.g. when equation A clarifies B, while B clarifies A), but we do not enforce it.

A problem is characterized by its visual representation, an answer, and a detailed solution. Both answers and solutions are given by their visual representations.

A problem is explicitly associated by the course author with variables (association 3 in Fig 2) and equations

Tretiakov A., Kinshuk & Tretiakov T. (2003). Designing Multimedia Support for Situated Learning. In V. Devedzic, J. M. Spector, D. G. Sampson & Kinshuk (Eds.) *The 3rd IEEE International Conference on Advanced Learning Technologies Conference Proceedings*, Los Alamitos, USA: IEEE Computer Society, 32-36 (ISBN 0-7695-1967-9)

(association 4 in Fig 2) that can serve as a hint for finding the solution. Again, specifying the correct associations is entirely the responsibility of the course author, and should be based on educational considerations. For example, in a series of similar problems the course author may wish to provide more hints for problems than occur earlier in the course.

In our prototype implementation [23], the data model given above is realized as an XML document describing the course. Variables with the associated information are encoded in the document header, while equations and problems are described in the document text as they occur. All objects are given unique IDs. Associations are encoded by using suitable markup techniques.

The XML document is rendered in DHTML by applying a suitably defined XSL transformation. To render equations and variables, we used their representation as images.

Equations occurring in the document are automatically numbered, and numbers are displayed next to equations as they are rendered. Any hot links to equations are rendered as their numbers.

Navigation structure is illustrated in Fig. 2 by arrows at association ends.

An equation is connected to variables and other equations it is associated with. In the prototype [23], variables (their symbolic representation, short description and dimensionality), and equations (with hot links to their locations in the document) are listed in a pop-up window, shown when one clicks on the equation image (Fig. 3).

A problem definition is accompanied by three hot links: a hint link, an answer link, and a solution link (indicated in the prototype by, respectively, spades, diamonds and hearts marks, see Fig. 4a). The hint link pops up a window with a hint, composed as a list of relevant variables and equations (with hot links to their locations in the document), associated with the problem (Fig. 4b). The answer link pops up a window with the problem answer (Fig. 4c). The solution link incorporates a possible solution of the problem into the main body of the course (Fig. 4d).

a) b)

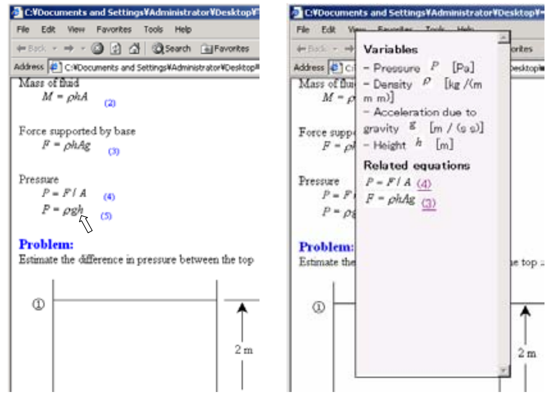
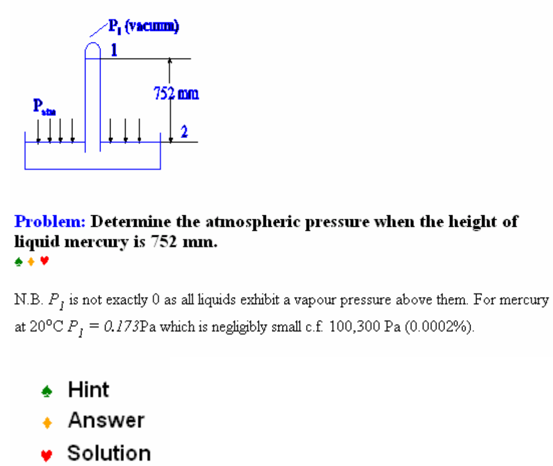
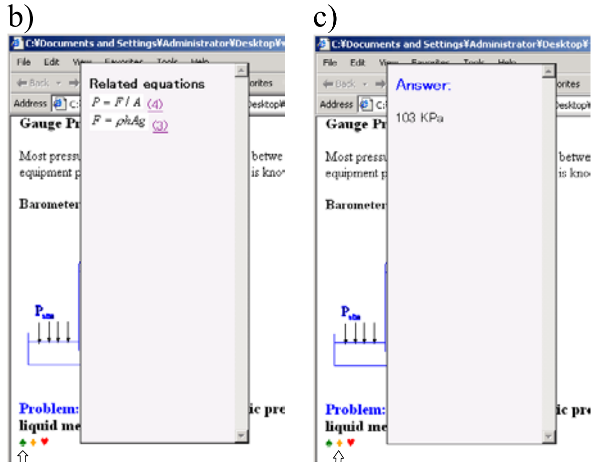


Figure 3 Navigating from an equation

a)



b) c)



Tretiakov A., Kinshuk & Tretiakov T. (2003). Designing Multimedia Support for Situated Learning. In V. Devedzic, J. M. Spector, D. G. Sampson & Kinshuk (Eds.) *The 3rd IEEE International Conference on Advanced Learning Technologies Conference Proceedings*, Los Alamitos, USA: IEEE Computer Society, 32-36 (ISBN 0-7695-1967-9)

d)

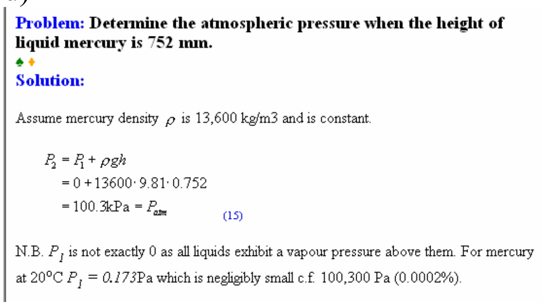


Figure 4 Navigating from a problem

5. Conclusions

We formulated an architecture for multimedia systems designed to support situated learning. The viability of the architecture was confirmed by applying it in the case of domains relying on the use of dimensioned variables and equations, and by implementing a prototype.

At present, our approach does not address the needs of content creators, which is essential for widespread adoption. Extension and refinement of the architecture to support course creation activities (by teachers) is a topic for further research.

References

[1] J.S. Brown, A. Collins and P. Duguid, "Situated Cognition and the Culture of Learning", *Educational Researcher*, v. 18, 1989, pp. 32-42.

[2] E. Bredo, "Cognitivism, Situated Cognition, and Deweyan Pragmatism", in *Proceedings of the Fiftieth Annual Meeting of the Philosophy of Education Society*, M.S. Katz (ed.) , Charlotte, North Carolina, 1994.

[3] W.J. Clancey, "A tutorial on situated learning". in *Proceedings of the International Conference on Computers and Education*, J. Self (ed.), Charlottesville, Virginia, 1995.

[4] R.J. Spiro, P.J. Feltovich, M.J. Jacobson and R.L. Coulson, "Cognitive Flexibility, Constructivism, and Hypertext: Random Access Instruction for Advanced Knowledge Acquisition in Ill-Structured Domains", in *Constructivism in Education*, L. Steffe and J. Gale (eds.), Hillsdale, New Jersey, 1995.

[5] C.A. Hansman and A.L. Wilson, "Cognition and Practice - Adult Learning Situated in Everyday Activity", in *Adult Education Research Conference (AERC) Proceedings*, J.C. Kimmel (ed.), San Antonio, Texas, 1998.

[6] Ch. Sinha, "Situated Selves: Learning to be a Learner", in *Learning Sites: Social and Technological Resources for Learning (Advances in Learning and Instruction Series)*, J. Bliss, R. Saljo and P. Light (eds), Pergamon, Oxford, 1999.

[7] N.A. Fabio and A. John, "Self, System Intelligence in Constructivist Learning", *International Journal of Artificial Intelligence in Education*, v. 11, 2000, pp. 344-376.

[8] G.A. Miller and P.M. Gildea "How children learn words", *Scientific American*, v. 257, 1987, pp. 94-99.

[9] Cognition and technology group at Vanderbilt, "Anchored Instruction and Its Relationship to Situated Cognition", *Educational Researcher*, v. 19, 1990, pp. 2-10.

[10] J.D. Bransford, R.D. Sherwood, T.S. Hasselbring, C.K. Kinzer and S.M. Williams. "Anchored instruction: Why we need it and how technology can help", in. *Cognition, education, and multimedia: Exploring ideas in high technology*, D. Nix and R. Spiro (eds.), Hillsdale, New Jersey, 1990.

[11] Cognition and technology group at Vanderbilt, "Anchored Instruction and Situated Cognition Revisted", *Educational Technology*, v. 33, 1990, pp. 52-70.

[12] A. Collins, J.S. Brown and S.E. Newman, "Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics", in *Knowing, learning, and instruction: Essays in honor of Robert Glaser*, L. B. Resnick (ed.), Hillsdale, New Jersey, 1990.

[13] K. Van Lehn, "Conceptual and Meta Learning During Coached Problem Solving", in *Intelligent Tutoring Systems*, C. Frasson, G. Gauthier and A. Lesgold (eds.), Montreal, Canada, 1996.

[14] A. Patel, D. Russell and Kinshuk, "Assessment in a Cognitive Apprenticeship Based Learning Environment - Potential and Pitfalls", in *Computer-Assisted Assessment in Higher Education*, S. Brown, P. Race and J. Bull (eds.), Kogan Page, London, 1999.

[15] J. Tholander and K. Karlgren, "Support for Cognitive Apprenticeship in Object-Oriented Model Construction", in *Computer-Supported Collaborative Learning*, Boulder, Colorado, 2002.

[16] Kinshuk, R. Oppermann, A. Patel and A. Kashihara, "Multiple Representation Approach in Multimedia-based Intelligent Educational Systems", in *Artificial Intelligence in Education*, S. P. Lajoie and M. Vivet (eds.), IOS Press, Amsterdam, 1999.

[17] J. S. Gero and R. Reffat, "Multiple representations as a platform for situated learning systems in designing", *Knowledge-Based Systems*, v. 14, 2001, pp. 337-351.

[18] R. Oliver, A. Herrington, J. Herrington and L. Sparrow, "Using situated cognition in the design of interactive multimedia-based learning environments", in *Proceedings of the Japanese Educational Technology Annual Conference*, Kanazawa, Japan, 1996.

[19] T. Crews, G. Biswas, S. Goldman and J. Bransford, "Anchored Interactive Learning Environments", *International Journal of Artificial Intelligence in Education*, v. 8, 1997, pp. 142-178.

Tretiakov A., Kinshuk & Tretiakov T. (2003). Designing Multimedia Support for Situated Learning. In V. Devedzic, J. M. Spector, D. G. Sampson & Kinshuk (Eds.) *The 3rd IEEE International Conference on Advanced Learning Technologies Conference Proceedings*, Los Alamitos, USA: IEEE Computer Society, 32-36 (ISBN 0-7695-1967-9)

[20] W. Van Joolingen, "Cognitive tools for discovery learning", *International Journal of Artificial Intelligence in Education*, v. 10, 1999, pp. 385-397.

[21] N. Henze and W. Nejdl, "Constructivism in Computer Science Education: Evaluating a Teleteaching Environment for Project Oriented Learning", in *Interactive Computer aided Learning - Concepts and Applications*, Villach, Austria, 1998.

[22] A. Inaba, T. Supnithi, M. Ikeda, R. Mizoguchi and J. Toyoda, "An Overview of 'Learning Goal Ontology'", *ECAI2000 Workshop Notes-XXVI*, Berlin, Germany, 2000.

[23] Our proof-of-concept prototype can be accessed at `http://is-alt.massey.ac.nz/vr/vr.xml`. It requires Internet Explorer 6.0 or later.