Studies in Learning, Evaluation Innovation and Development

http://sleid.cqu.edu.au
2(1), pp. 10–19. 2005

CAMPUS—computer-based training in medicine as part of a problem-oriented educational strategy

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Abstract

Computer-based training (CBT) systems can efficiently support modern teaching and learning environments. [CAMPUS is one example of such a system—supporting medical education based on real medical cases using a constructivist learning approach.] CAMPUS is now available in English and is used for teaching and learning in medicine, but also supports teaching and learning in nursing. In this paper, we demonstrate, on the basis of CAMPUS, that long-established and current learning theories and design principles (e.g., Bloom's Taxonomy and practice fields) are (i) relevant to CBT and (ii) are feasible to implement using computer-based training and adequate learning environments. Not all design principles can be fulfilled by the CBT system alone; the integration of the system with adequate teaching and learning environments therefore is essential. Adequately integrated, CBT programs become valuable means to build or support practice fields for learners and build domain knowledge and problem-solving skills. Learning theories and their design principles can assist in designing these systems as well as in assessing their value.

This article has been peer-reviewed and accepted for publication in *Studies in LEID*, an international journal of scholarship and research that supports emerging scholars and the development of evidence-based practice in education. ISSN 1832–2050

Introduction

For students of medicine or nursing, learning means to become familiar with clinical cases and problems and the procedures involved. The best way to do this is to directly involve the students in the delivery of health care. But 'real' patients with a particular disease are not always available. Often there is no appropriate patient or a patient can not be presented to all students because of practical or ethical problems. Actors as standardised patients are a solution; however, their value is limited: most results of pathological examinations cannot be accurately simulated by them.

Computer-based training (CBT) programs, which are available at any time and place, possibly offer a solution to these problems. Most CBT-programs in health care, however, are based on a simple presentation concept. Clinical problems are presented to the student in a linear way, thus limiting interactivity to answering some multiple-choice questions. This concept might be suitable for users with a higher level of professionalism, e.g., for Continued Medical Education (CME); however, for a student who needs to learn a strategy to cope with real clinical problems this concept is not suitable. Further, simulations of patients by a computer program are often limited to a certain medical field. For authors and users to accept the system, it has to be highly *flexible* and *realistic*. Flexibility requires that cases from different medical fields can be demonstrated by the same system in a different way and in harmony with the various user demands. Reality requires that the examinations and mistakes a physician is able to do in practice could be done by the student using the system in a similar way—but without the potential of errors leading to undesirable consequences for patients.
The University of Heidelberg, Germany, developed a flexible and realistic system for computer-based training in medicine as part of a problem-oriented educational strategy (CAMPUS), (Riedel, Singer, Leven, Geiss, & Tönshoff, 2000).

While this introduction gave a medical example of computer-based training and the underlying educational problems, theories of good learning and design principles for good learning experiences are neither specific to medicine nor specific to CBT. Therefore, it is the aim of this paper to:

- outline current learning theories and demonstrate their *relevance* to computer-supported learning
- demonstrate on the basis of CAMPUS that these theories can successfully be applied in computer-based training (*feasibility*).

Learning theories and computer-based training

Current theories of learning acknowledge that learning is a wilful, intentional, active, conscious, constructive activity that requires reciprocal intention-action-reflection cognition. The theories therefore emphasise the importance of learner-centred, active, authentic environments for meaningful knowledge construction (constructivism). The shift from behaviourism and cognitivism to more constructivist-oriented learning theories asserts that learning is a process of meaning making, not of knowledge transmission, and that it is a social-dialogical process influenced by communities of practice. The movement to a constructivist-learning paradigm has influenced the design and development of open-ended learning environments such as problem-based learning (Hmelo, 1998) and goal-based scenarios (Schank, Fano, Bett, & Jona, 1994). Cases should 'tell stories' and the narrative can be central to the understanding of the case.

Computerised case-based learning systems can efficiently build or support practice fields for learners to build domain knowledge and problem-solving skills and to support contextualised transfer of knowledge and skills to professional practice (Jonassen, 2000). Computer-based learning systems can facilitate this 'constructivist' type of transfer by bringing real world problems into the learning space and by providing performance feedback and opportunities for meta-cognitive reflection tied to authentic problems (National Research Council, 2000).

Bloom's taxonomy

Bloom, an educational psychologist, developed a classification of levels of intellectual behaviour (Bloom, 1956). The classification featured the following levels of intellectual behaviour:

1. knowledge (the lowest level, pure recall of data)
2. comprehension (understand the meaning)
3. application (use a concept in a new situation)
4. analysis (identify components, see patterns)
5. synthesis (put parts together to form a new whole)
6. evaluation (the highest level, make judgments about the value of ideas or materials).

Bloom found that over 95% of the test questions students encounter require them to think only at the lowest possible level, the recall of information; however, it is important for learning to be challenged on all levels of intellectual behaviour. Although not developed in light of constructivism, we use Bloom's Taxonomy in this paper to discuss basic principles of intellectual (learning) behaviour relevant for CBT systems. Since its initial publication in 1956, Bloom's Taxonomy has continuously been expanded by Bloom and other contributors, even as recently as 2001 (Anderson & Krathwohl, 2001), extending Bloom's work to far more complex levels than described here. However, Bloom's simpler original taxonomy is still often used e.g., to assess difficulties in academic exams or assessments or corporate training and development.

Practice fields

In practice fields (Senge, 1994) students engage in the kinds of problems and practices that they will encounter outside of school. *Knowing about* refers to an activity—not a thing; is always contextualised—not abstract; and is reciprocally constructed within the individual-environment interaction—not objectively defined or subjectively created (Barab, Hay, & Duffy, 1998). Preparing practice fields involves creating realistic activities or experiences for the learner. These activities must present most of the cognitive demands the learner would encounter in the real world to foster authentic problem solving and critical thinking in the domain. Problem-based learning is one example of practice fields. Problem-based learning builds domain knowledge and problem-solving skills in realistic situations. To maximise the usefulness of practice fields, design principles have been introduced by Barab and Duffy (2000). These principles are summarised in Table 1.

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Table 1: Design principles for practice fields as proposed by Barab & Duffy, 2000

Principle 1: Doing domain-related practice	Learners must be actively doing domain-related practice, not listening to the experiences or findings of others.
Principle 2: Ownership of the inquiry	Learners must see the dilemma as worth investing their efforts. They must feel they are responsible for the solution.
Principle 3: Coaching and modelling of thinking skills	The instructor's job (a real instructor or the learning system) is to coach and model learning and problem solving by asking questions that learners should be asking themselves.
Principle 4: Opportunity for reflection	Reflection provides individuals with the opportunity to think about why they are doing what they are doing and even to gather evidence to evaluate the efficacy of their decisions. The reflective process is essential to the quality of learning.
Principle 5: Dilemmas are ill-structured	Dilemmas in which learners are engaged must be either ill-defined or loosely structured so that learners can impose their own problem frames.
Principle 6: Support the learner rather than simplify the dilemma	The dilemmas that learners encounter should reflect the complexity of the thinking and work that they are expected to meet in the real world.
Principle 7: Work is collaborative and social	Meaning is a process of continual negotiation. The quality and depth of this negotiation and understanding can only be determined in a collaborative social environment where ideas are discussed in communities of practice.
Principle 8: The learning context is motivating	Learners must be introduced to the context of problems and their relevance, and this must be done in a way that challenges and engages the learner.

CAMPUS—cased-based learning in medicine

With their potential to provide interactive multimedia applications, computers can be used to simulate realistic situations. Knowledge and skill acquisition can be significantly greater with computer-based compared to lecture-based teaching (Williams, Aubin, Harkin, & Cottrell, 2001). Unlike real situations, the simulated ones can be faced at the time needed, that is, at the time it is educationally wise or at the time the learner or individual desires.

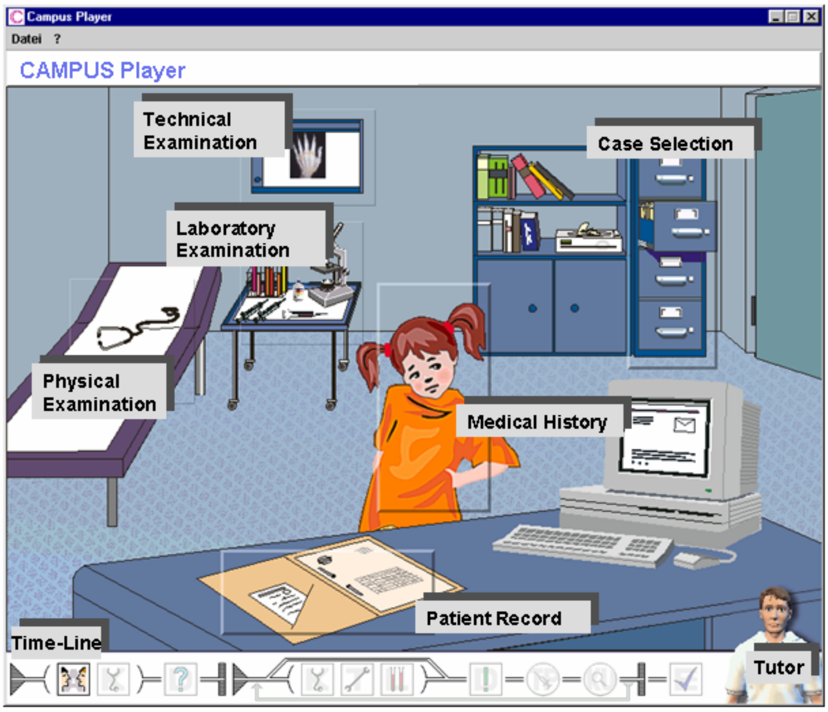
CAMPUS will be used as an example for computer-based learning systems to show that it is possible to implement the practice field design principles (Barab & Duffy, 2000) in computer-based learning systems and cover all levels of Bloom's Taxonomy.

The CAMPUS system

CAMPUS is a web-based learning shell system to develop and provide flexible, simulative real medical multimedia cases for use by educators, students, and physicians at different levels. It consists mainly of a user friendly authoring system as the tool for case-data input and a player component as the learner's front-end (Figure 1). The CAMPUS system supports the authors of medical cases with appropriate vocabularies and a comfortable authoring tool. It features different kinds of case presentations in accordance to the level of professionalism of the user and the type of scenario to be used.

The main screen represents a situated learning environment with familiar medical images and elements that provide an easily understandable, realistic, user interface. While working through a case, the learner is able to consult the patient record for results. The tutor gives expert comments and asks questions. At the bottom of the interface, a timeline shows the current status within the case structure. With the aid of this interface, the user tries to solve a medical case in a simulative manner, which means that he/she can do just about everything he/she wants to do (e.g., medical history taking, physical and technical exams, lab tests). To provide didactic elements, the case author can define expert comments and knowledge questions. At each feedback point the user gets feedback with respect to his/her decisions by presenting a comparison between measures and the procedures which the author of the case considers to be right, distinguished by different colours. The feedback provided is neutral without messages like 'very good' or 'bad answer'. CAMPUS avoids such messages because of the different possible ways of solving a case, that is, the teacher or system's role is not directive.

Figure 1: The CAMPUS Player—main screen



CAMPUS and Bloom's Taxonomy

The levels of Bloom's Taxonomy can be thought of as degrees of difficulties and it is sometimes regarded as essential to master the first one before the next level can be aimed at. However, this cannot be achieved as thoroughly in health care as in other fields—not only is health care big, it is open-ended (Garde, Hovenga, & Conrick, 2004):

- In breadth, because new knowledge is always being discovered or becoming relevant.
- In depth, because finer-grained detail is always being discovered or becoming relevant.
- In complexity, because new relationships are always being discovered or becoming relevant.

As a consequence, Health Professionals constantly have to deal not only with insufficient information (about the patient) all the time, but also with insufficient knowledge (of the diagnoses, the treatment, etc.). This makes it even more important that Health Professionals constantly learn on all levels of Bloom's taxonomy. Cases cannot be structured to apply to one level of Bloom's taxonomy only (and in fact should not—taking into account the findings of constructivist-oriented learning theories!). Cases, however, can be structured according to their degree of difficulty to focus more on lower levels of Bloom's taxonomy (knowledge, comprehension and application) or focus more on higher levels of the taxonomy (analysis, synthesis and evaluation); however, for example, given the open-ended health care, simple knowledge questions will still be relevant in cases of higher difficulty. Table 2 shows examples from CAMPUS which address the different levels of Bloom's Taxonomy thus showing that the system engages the learner on all levels of Bloom's Taxonomy.

Table 2: CAMPUS offers learning on all levels of Bloom's taxonomy. Examples for each level are given in this table.

Level in Bloom's Taxonomy	**Example in CAMPUS**
Knowledge	Answer knowledge questions added by the case author.
Comprehension	Interpret single lab test results (e.g., a value is extremely high).
Application	Conduct efficient physical examination; conduct efficient medical history taking.
Analysis	Analyse lab results and draw conclusions; analyse physical examination and draw conclusions.
Synthesis	Analyse lab results *and* analyse physical examination and draw conclusions, e.g., diagnosis and prognosis.
Evaluation	Evaluate your own behaviour when comparing it with the case expert's 'solution'; assess value of external medical knowledge found.

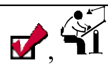
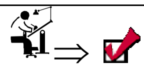
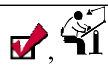
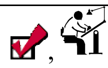
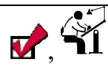
CAMPUS and the practice field design principles

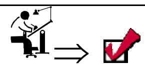
In the following Table 3 we analyse to what extent CAMPUS—as an example for CBT—fulfils the design principles of practice fields. In this context we differentiate between 3 ways to fulfil the principle:

1. The CAMPUS-system fulfils the principle independent of the environment. This is indicated by  in the following.
2. The CAMPUS-system provides the basis to fulfil this principle, but in addition a good environment[1] is needed to fulfil this principle. This is indicated by  ⇒ .
3. The CAMPUS-system fulfils the principle independent of the environment, but additionally a good environment can further contribute to this principle, indicated by , .

[1] e.g., a case-author providing well-designed medical cases or a good integration into learning management systems like WebCT or .LRN.

Table 3: Design principles of practice fields and how they are fulfilled in CAMPUS.

Principle 1: Doing domain-related practice	Because of the simulative and interactive nature of the system, the workout of a case is domain-related learning by doing, not listening to the experiences or findings of others. Further, certain technical examinations might not be available at a given point of time, so that the student has to improvise—just as in real life.	
Principle 2: Ownership of the inquiry	Obviously, from a learning point of view treating a real patient would be the best approach. For reasons discussed before this is not always possible. Nevertheless a feeling of ownership is achieved by using real medical cases. Patient images and videos intensify this effect. Because of the simulative format (e.g., talking to the patient during medical history taking) and use of neutral feedback, students can develop their own solution.	
Principle 3: Coaching and modeling of thinking skills	Coaching of thinking skills is dependent on the program's author. She/he can create expert comments that are shown on demand or guide by asking the right questions or displaying the right hints. It is the author's responsibility to use this capability in the right way to coach the learner.	
Principle 4: Opportunity for reflection	CAMPUS supports reflection in several ways: • By ordering single examinations and getting specific results, the user has to think about the results and decide on the next step to proceed. • Users must reflect in the feedback components where a comparison between the author's solution and their own is given. • Knowledge questions and expert commentary and hints can be used to prompt the student to think about special parts of the case.	
Principle 5: Dilemmas are ill-structured	CAMPUS supports ill-structured and complex dilemmas by offering the user maximum and case-independent possibilities of examinations, diagnoses, and therapies. Again, the neutral feedback is important in this context. Without neutrality, the user would wait for feedback after each action and individual problem-solving approaches would not develop.	
Principle 6: Support the learner rather than simplify the dilemma	CAMPUS does neither simplify medical cases nor restricts the decisions that can be made. Rather, it supports the learner in several ways. Apart from the aforementioned knowledge-on-demand expert comments, questions, and hints, CAMPUS also provides more systematic knowledge: easy accessible integrated digitised textbook knowledge and access to online libraries in a context-sensitive manner.	
Principle 7: Work is collaborative and social	CAMPUS offers important views of others by providing a comparison between the author's and the learner's solution. Other collaborative and social tenets are mainly system-independent and learning-scenario-dependent. An example of an appropriate scenario is that of students working on several cases in groups of two to three persons per computer as recommended through different studies, e.g., (Johnson & Johnson, 1992), assisted by a tutor. After completion, all students discuss the case together with the tutor.	

	If integrated into a learning management system (LMS), students can learn collaboratively by discussing the CAMPUS cases.	
Principle 8: The learning context is motivating	Because the aim of CAMPUS is to integrate real cases into training, these problems engage the learner. The web-based approach and case repositories offer rich opportunities for using CAMPUS in communities of practice. In such communities, students as well as teachers and physicians can easily contribute interesting, community-concerned cases via CAMPUS' authoring system and discuss them.	

Discussion

Many of the current learning theories focus on authentic, student-centred learning environments. As Jonassen and Land stated (Jonassen & Land, 2000), the past decade "has witnessed the most substantive and revolutionary changes in learning theory in history" (p. iv). In fact, newer theoretical learning foundations—such as socially shared cognition, situated learning, everyday cognition and reasoning, activity theory, ecological psychology, distributed cognition, and case-based reasoning—share many of the beliefs and assumptions of constructivism.

Good educational practice principles are independent of the domain (e.g., medicine) and the degree of technology supporting the learner or teacher. In this context, practice field principles and Bloom's Taxonomy are a valuable means to assess the teaching provided. As shown in this paper, all of the practice field principles are achievable with interactive computer-based learning systems. Some of these principles, however, cannot be fully fulfilled by the application program alone but are partially dependent on how the learning environment is designed and on the quality and suitability of the cases designed by case authors.
Bloom's Taxonomy—defining levels of intellectual behaviour—helps in determining on which levels the student is intellectually challenged. As shown in this paper, properly designed CBT programs can challenge the student on all levels of Bloom's Taxonomy. In CAMPUS, the challenges on the different levels are interwoven—this reflects the real world situation of health professionals who do not have the luxury of being able to obtain a comprehensive knowledge of medicine.

In general, Schank's notions of case learning and constructivism (Schank et al., 1994) are nowadays much more common than the application of Bloom's taxonomy (although interesting differences between various countries can be observed). That principles of both approaches can be fulfilled by CBT systems; however, supports our argument that for 'good' teaching and learning environments CBT systems are invaluable, independent of how 'good' is being measured. We did not explicitly regard in this paper the whole notion of communities of practice (Lave & Wenger, 1991) which is directly relevant to medical and nursing professions; however, it is argued that when it comes to the actual design of learning contexts based on practice fields or communities of practice, similar principles are relevant (Barab & Duffy, 2000).

Two evaluation studies have shown that the CAMPUS concept is regarded as useful by medical students. Evaluation results are described elsewhere in detail (Riedel, Fitzgerald, Leven, & Tönshoff, 2003; Ruderich et al., 2002), but in summary 80.7% (176 out of 218 students who participated in a pediatric internship at the Heidelberg Medical Centre) liked learning with CAMPUS; 72% (157) rated learning with CAMPUS as effective; 73.5% (160) said that learning with CAMPUS was motivating for further learning; and 69.3% (151) would like to use CAMPUS within the curriculum. In addition, in 2002, CAMPUS won the MedidaPrix, a well-known and highly desired European prize for media and didactics (Medida Prix 2005).

An English version of CAMPUS is now available (Heid et al., 2004), and CAMPUS can now be used by universities in Australia or other English-speaking countries. CAMPUS can be used for teaching and learning in medicine, but cases can also be adapted to support teaching and learning in nursing.

Conclusion

Constructivism and CBT systems are valuable means for modern teaching and learning environments. Learning theories and their design principles can support in designing these systems as well as in assessing their value. While acknowledging the difficulties inherent in simulating reality as an interactive learning scenario, we found on the basis of CAMPUS that important design principles for effective learning environments can be fulfilled by the application of computer-based training.

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