Computer-based Training in Medicine and Learning Theories

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Abstract

Computer-based training (CBT) systems can efficiently support modern teaching and learning environments. In this paper, we demonstrate on the basis of the case-based CBT system CAMPUS that current learning theories and design principles (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 system alone, the integration of the system in adequate teaching and learning environments therefore is essential. Adequately integrated, CBT programs become valuable means to build or support practice fields for learners that build domain knowledge and problem-solving skills. Learning theories and their design principles can support in designing these systems as well as in assessing their value.

Keywords: Computer-Assisted Instruction; Problem-Based Learning; Medical Informatics

1. Introduction

For students of medicine or nursing, learning means to become familiar with clinical cases and problems. 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 an appropriate patient is missing or can not be demonstrated to all students because of practical or ethical problems. Computer-based training (CBT) programs, which are available at any time and place possibly offer a solution to these problems. Therefore, the University of Heidelberg, Germany, developed CAMPUS, a web-based learning shell system to 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 features different kinds of case presentations in accordance to the level of professionalism of the user and the scenario the program is used in. 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. 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 (as in real life, e.g., anamnesis, physical and technical exams, lab tests). The learner can do a physical exam by choosing the kind of exam (e.g., auscultation) and pointing to a specific body region. 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 his 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.

This paper outlines current learning theories, demonstrates their relevance to computer-supported learning and shows on the basis of CAMPUS that these theories can successfully be applied in computer-based training.

2. Materials and methods

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 emphasize the importance of learner-centred, active, authentic environments for meaningful knowledge construction (constructivism). The fundamental shift to 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 like problem-based learning [1] and goal-based scenarios [2].

Figure 1 - The CAMPUS Player – main screen
Computerized case-based learning systems can efficiently build or support practice fields for learners to build domain knowledge and problem-solving skills and to support contextualized transfer of knowledge and skills to professional practice [3]. 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 [4].

2.1 Bloom’s Taxonomy

Bloom developed a classification of levels of intellectual behaviour [5]. The classification features 6 levels of intellectual behaviour: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. It is important for learning to be challenged on all levels of intellectual behaviour. Although not developed in light of constructivism, Bloom’s Taxonomy is still often used e.g. to assess difficulties in exams or assessments.

2.2 Practice Fields

In practice fields [6] students engage in the kinds of problems and practices that they will encounter outside of school. Preparing practice fields involves creating circumscribed realistic activities or experiences for the learner. These activities must be authentic; they 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 during the professional preparation years is more than practicing future skills; it builds domain knowledge and problem-solving skills in realistic situations. To maximize the usefulness of practice fields, design principles have been introduced by [7]. These principles are summarized in Table 1.

| 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 modeling 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 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 social environment where ideas are discussed. |
| 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. |
3. Results

CAMPUS offers learning on all levels of Bloom’s taxonomy. The following enumeration gives some examples:

1. Knowledge: Answer knowledge questions added by the case author.
2. Comprehension: Interpret single lab test results (e.g. a value is extremely high)
3. Application: Conduct efficient medical history taking and efficient physical examination
4. Analysis: Analyse lab results and draw conclusions; analyse physical examination and draw conclusions
5. Synthesis: Analyse lab results and analyse physical examination and draw conclusions, e.g. diagnosis and prognosis
6. Evaluation: Evaluate your own behaviour when comparing it with the case expert’s “solution”; assess value of external medical knowledge found.

Below we analyse how far CAMPUS as an example for CBT fulfils the design principles of practice fields. Table 2 summarizes the findings.

Table 2: 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 | A feeling of ownership is achieved by using real medical cases. Patient images and videos intensify this effect. Because of the simulative format 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 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 digitized 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., [8], assisted by a tutor. After completion, all students discuss the case together with the tutor. CAMPUS also can be integrated into learning management systems (LMS) such as .LRN. Within the 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 can easily contribute interesting, community-concerned cases via CAMPUS’ authoring system and discuss them. |

While CAMPUS fulfills principle 1 and 5 independent from the teaching and learning environment to fulfill the other principles in addition a good teaching and learning environment is mandatory.

### 4. Discussion

Many of the current learning theories focus on authentic, student-centred learning environments. As Jonassen and Land stated [3], the past decade “has witnessed the most substantive and revolutionary changes in learning theory in history”. 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 CBT systems. Some of these principles, however, cannot be fully fulfilled by the application program alone but are partially dependent on how the teaching and 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.

Two evaluation studies have shown that the CAMPUS concept is regarded as useful by medical students. Evaluation results are described elsewhere in detail [9], 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.

### 5. Conclusion

Constructivism and CBT programs 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. As shown in this paper these design principles can be fulfilled by integrated computer-based training teaching and learning environments.

6. References


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