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TOWARDS A FRAMEWORK OF USING KNOWLEDGE TOOLS FOR TEACHING BY SOLVING PROBLEMS IN TECHNOLOGY-ENHANCED LEARNING ENVIRONMENT*

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ABSTRACT

Problem solving is a critical competency for modern world and also an effective way of learning. Education should not only transfer domain-specific knowledge to students, but also prepare them to solve real-life problems – to apply knowledge from one or several domains within specific situation. Problem solving as teaching tool is known for a long time, but our aim is to enhance it by suggesting knowledge tools for different stages of problem solving process. Knowledge tools involve students in the process of knowledge construction that contributes to understanding of subject and help students to organize and present their own knowledge. An overview of software, which help to apply the suggested knowledge tools, is presented as well. Finally we illustrate our approach with two examples of teaching school and university students.

KEYWORDS

Education, problem solving, knowledge tools, knowledge construction, technology-enhanced learning

1. INTRODUCTION

Contemporary world requires the use of new technologies in learning process as the traditional educational methods cannot manage increasing amount of information. Education should not only give information to students, but also provide the methods of knowledge production and information technologies can make this process more effective and efficient. The use of IT in education should not be limited by the change of the communication channel for information transfer: "from teacher to learner" to "from the multimedia system to learner." Computer technology should provide conditions for students to design, present and express their knowledge by themselves rather than on a pre-programmed pattern (Jonassen et al, 1998; Jonassen, 2005). The learning environment is necessary to provide an opportunity for students to produce, present and express knowledge. The use of computers in this case means not only the use of various forms of presentation and communication of information (Kalantarov, 2014).

The use of problem-solving method in the learning process helps students in construction of their own knowledge and allow instructors to individualize the learning process, as students will generate their own decisions with the teacher's support and not use the already existing ones (Jonassen, 2004). This helps to understand the studied subjects better and improve problem-solving skills, regardless of the field of study.

Existing research (De Corte et al, 2004) shows the effectiveness of applying problem solving for educational results and improvement of learning and adaptation skills, but the suggested environment does not specify the role of IT. Computer system in this case should serve as a catalyst for the acquisition of knowledge and skills. Other research (Kim, Hannafin, 2011) illustrates the possibilities of scaffolding problem solving in technology enhanced environment, but without use of knowledge tools.

Knowledge tools help in the transfer of knowledge from teacher to student, making the process more clear and understandable, and enable students to construct their own knowledge and mental models. Knowledge tools involve students in the process of knowledge construction that contributes to understanding of subject, and not only the playback from the memory of what has been received from a teacher or other source of knowledge. These tools help students to organize and present their own knowledge. That is why we decided

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to make an environment where students would be given the opportunity to use knowledge tools to construct their own mental models and apply them to solve problems.

The aim of this paper is to propose a framework of using knowledge tools for teaching by solving problems and to suggest a corresponding IT support.

2. PROBLEM SOLVING AS A TEACHING TOOL

Problem solving is usually one of the most important cognitive skills in education, profession and everyday life (Jonassen, 2000). Problem is the task that requires study and subsequent decision, that contains the following (Jonassen, 1997): domain, type, solving process and solution. Domain defines concepts and elements of issues, concepts and principles adopted by it. Solving process is a set of operations to reduce the impact of the problem and to approach targets (Wood, 1983). Problem type prescribes the rules and procedures necessary for its solution. Well-structured and ill-structured problems can be allocated (Jonassen, 1997). Dividing problems in two categories is important for our framework because different types of problems can appear and different kinds of tools can be used for them. We summarized characteristics of problems in Table 1 (Jonassen, 1997; Wood, 1983; Kitchner, 1983).

Table 1. Characteristics of well- and ill-structured problems

	Well-Structured	**Ill-Structured**
Context dependence	Weak	Strong
The initial state	Well defined	Undefined
The final (target) state	Well known	Unknown
Number of solutions	One solution	Many solutions
Similar problems	Similar solution	Solutions can differ because of context dependence
Required skills	Knowledge Base	Personal experience in the field of problem Extensive knowledge of the issues and related fields The ability to argue and defend their point of view
Solving process	Spent circuit solutions Iterative search	Design and synthesis solutions Collection of evidence in favor solutions Discussions for the selection decision Monitoring of selected solutions
Evaluation	The effectiveness of the chosen schema	Only empirically
Relation with real life	Weak	Most real-world problems

According to (Jonassen, 2004; Kim, Hannafin, 2011) we can highlight the following stages of solving process for different types of problems: 1. Identify problem; 2. Create problem space (including context); 3. Search potential solutions; 4. Evaluate and choose solutions; 5. Implement solution; 6. Check and verify; 7. Reflection.

3. KNOWLEDGE TOOLS FOR TEACHING BY SOLVING PROBLEMS

The use of knowledge tools helps in the construction of knowledge by a student and becomes a key ingredient of active and continuous learning (Gavrilova, 2010; Gavrilova et al, 2011; Jonassen et al, 1998; Jonassen, 2005; Koznov, Pliskin, 2008). The article (Wang et al., 2013) illustrates the possibilities of using cognitive tools to scaffold the whole problem solving process and shows its effectiveness. Argument and concepts maps are used there together.

The current work is in line with the design science research methodology. The following requirements are specified for the framework: support of different stages of problem solving process; application of tools, which supports knowledge structuring and production; specifics of problems must be taken in to account; guidelines for implementation of IT support must be provided.

We analyzed and selected knowledge tools that can be applied effectively at different stages of problem-solving in teaching. The main sources of information were (Jonassen, 2005; Gavrilova et al, 2012; Young, 2010; Kudravtsev, Gavrilova, 2017). Our framework does not mean the use of all the proposed knowledge tools, but shows possible ones. Although some tools may be used at several stages, we tried to define the most important "stage-tool" links. The selection criterion for tools was a type of knowledge that is needed at the stage of problem solving. Also those tools were selected that are easy to learn and do not require a lot of time to study because they are ancillary.

3.1 Framework of Using Knowledge Tools on Stages of Problem Solving

The main part of our framework is based on visual knowledge structuring tools. First of all, elements of problem should be presented by student. Problem presentation is the key to problem solving (Jonassen, 2005). Knowledge visualization facilitates intuitive understanding (Mayer, 1989). Main parts of a problem situation and actions in problem-solving process as well as their relationships should be visualized. Mind maps can be used to show them. Then we should create problem space: understand relations between problem elements. Concept maps can visualize all relations. For ill-structured problems we should take into account context dependencies as well and simple overview of similar problems cannot give enough information in current situation. So causal models can be used to describe root causes and different consequences of a problem, they can also illustrate by (+) factors, that have positive impact, and by (-) factors, that have negative impact. The goal tree can be used for ill-structured problem because it can have multiple target states, which are associated to different goals, and we don't know the best one. Both well- and ill-structured problems can have several methods of solution: in this case, decision tree helps to visualize them. Argument mapping can help during choosing the best solution of that have been found by visualizing benefits and limitations of them. Such an evidence in favor or against solutions is especially relevant for ill-structured problems. When solution is chosen, diagrams may help to visualize its implementation plan in terms of projects and processes (for example, Gantt charts). After the implementation stage we should verify the solution. With argument map we can check solution by illustrating what have been and have not been done. On the last step mind map can be used again to summarize experience and make knowledge more structured. The framework is presented on table 2.

Table 2. Knowledge visualization tools supporting different stages of problem solving

Stage	Well-Structured problem	Ill-Structured problem
1. Identify problem	Mind map	
2. Create problem space (incl. context)	Concept map	
	–	Causal model
3. Search potential solutions	–	Goal tree
	Decision tree	
4. Evaluate and choose solutions	–	Argument map
5. Implement solution	Project diagram, Process diagram	
6. Check and verify	Argument mapping	
7. Reflection	Mind map	

However, not only knowledge visualization tools can be useful. Brainstorming can be used to identify problem in the group. Libraries with example solutions and case studies should help to understand meaningful objects of problem space and can show possible ways of the solution. Means-end analysis can be used for well-structured problems as we know initial and final state. For ill-structured problems brainstorm can help generate different solutions. Also decision tables can help to generate and organize possible solutions and then this tool can help to select the way to reach the best one. After action review and formulation of lessons learned can be used to evaluate chosen solution, get a feedback from students and accumulate their knowledge.

3.2 Software for Supporting Proposed Framework of Using Knowledge Tools

To scaffold our framework we reviewed some software tools to create heterogeneous technology-enhanced learning environment. Listed software (table 3) was chosen based on author's experience, literature review and product's descriptions.

Table 3. Software supporting knowledge visualization

Knowledge visualization tool	Possible software
Mind map	MindManager, MindMapper, ThinkGraph, FreeMind, MyMind, Xmind
Concept map	CmapTool, Inspiration
Argument map	Reason!Able, Athena, Debatabase, Agora, Rationale
Decision tree	PrecisionTree, Flying Logic
Project diagram	Microsoft Project
Process diagram	Microsoft Visio

Another option is software integrated in a learning management system. Benefit of this approach is that software tools are standardized and visual models can be produced, saved and checked directly in learning environment. Moreover, integration gives an opportunity to use one tool for knowledge transfer from teacher, knowledge construction by student and assessment of education results. We analysed Moodle system (https://moodle.org/) as an integration platform. Moodle is a learning platform designed to provide educators, administrators and learners with a single robust, secure and integrated system to create learning environments. Standard activities like forums, chats and wiki can be used for brainstorming, after action review and lessons learned and also to describe and accumulate cases and worked examples.

Visual knowledge tools can be installed as well. We have found activity plugins for mind mapping (Mind Map, Advanced MindMap, Mappa) and question type plugin for concept mapping (Concept Map). Hierarchical structure of mind maps allows using this tool for goal and decision trees, using colors on mind map can make it suitable for argument map creation and a complement of this tool by chat gives a visual tool for brainstorming. A substitution of relations in concept map by + and – allows to make causal models.

4. DEMONSTRATION

Our approach now is on the stage of approbation. For case and field studies we decided to implement our framework and added problem solving as an instrument of education in two courses: for programming learners at school and for university learners of business engineering (enterprise architecture).

First group includes school learners 14-15 years old that study programming and have a task of making course project. They should choose well-structured problem. To enhance this process it is required to build mind map of their problem to make it more obviously. After the information model of program was build students should apply means-ends analysis to make effective and optimized algorithm. If pupils do not implement it, they can choose any working solution without comparing so they will not get metacognitive skills. After making of programs all students will have to discuss not only their own works but try to evaluate other solutions through common after action review.

University students study business engineering (enterprise architecture) through semester-long problem-oriented project. They should choose an enterprise, find «bottle necks» and suggest solution. This task is ill-structured. Students create standard enterprise architecture models during analysis and synthesis phases of problem solving. Students should make a mind-map in order to organize knowledge about an enterprise and understand context. Goal tree is created and causal map for root-cause analysis is developed. Brainstorm can be applied for searching possible solutions by group. Overview of existing solutions for similar problems and work with case library will help to avoid wheel reinvention. Many solutions are possible because this problem is ill-structured – we cannot know the ideal goal state for enterprise. Argument mapping can help to choose the best solution and develop skills of reasoning and defending point of view. After the solution was created students have to consolidate gathered knowledge by formulating lessons learned.

It should be noted that the use of knowledge tools is an additional cognitive load. However, the expected effect of improving learning skills and deeper understanding of the subject, in our view, justifies this approach. Further research will be dedicated to more detailed analysis of relationship between knowledge tools and different stages of problem solving, besides more sound evaluation of the proposed framework is required.

5. CONCLUSION

Contemporary world requires the use of new technologies in learning process. Education should not only give domain-knowledge but has to provide the methods of knowledge production and information technologies can make this process more efficient. Principles of education through problem solving were discussed. Problems as educational instrument can let students get metacognitive skills and not only domain specific knowledges. To make the process of transferring of knowledge from teacher to student clearer and to help student construct own knowledge we proposed the framework of using knowledge tools and methods on different stages of problem solving. Knowledge tools involve students in the process of knowledge production that contributes to their profound understanding of subject. IT environment can help to make this process more effective. The results of the research can be used for creating courses and applying specific IT-tools and plugins on various stages of training.

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