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A Problem-oriented Approach to Represent and Manage Knowledge in PBL

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Abstract: In traditional subject-based learning knowledge is well-structured and prepared in advance by the teachers before transferring in the form of a lecture presentation. However, the knowledge learned in problem-based learning (PBL) may be multi-disciplinary / ill-structured, constructed collaboratively by a small group of learners. It is challenge to support teachers and students in representing and managing knowledge in an online and hybrid PBL environment. This paper presents a problem-oriented knowledge representation and management method based on an analysis of technical requirements to support online and hybrid PBL. Adopting this approach we develop a PBL-specific whiteboard, a visualized knowledge representation tool supporting collaborative knowledge building in PBL. Through a combined use of a PBL scripting language and the PBL-specific whiteboard, the students can be guided and scaffold to construct and share a network of knowledge artifacts systematically as they progress through their various activities such as defining problems, identifying learning issues, proposing ideas, and improving their ideas. In this paper we demonstrate the technical feasibility of this approach by presenting the implementation of a web-based PBL application.

Keywords: Problem-based learning, problem-oriented knowledge management, PBL scripting language, collaborative knowledge building

1. Introduction

Nowadays, the problems to which we face in real-world are normally complex and multi-disciplinary / faceted. The complex problems and knowledge economy requires graduates to have not only a certain knowledge-base but also the 21st century competences such as problem solving, critical thinking, being able to work in a team, and self-directed/regulated learning. However, in traditional subject-based learning approach, knowledge is well structured before it is passed on to the students. It does very little to improve students' problem-solving and critical thinking skills. The knowledge acquired by the students is usually inert and is quickly forgotten because this knowledge is not anchored in a context of authentic use.

In contrast, problem-based learning (PBL) encourages the development of such competences. PBL approach is learning and teaching approach that use authentic problem to drive the learning process and assess the learning outcomes (Barrows 1989). Through the PBL approach real-life context and technologies are brought into the curriculum which encourages students to become independent workers, critical thinkers, lifelong learners, problem solvers and team workers (Hmelo-Silver and Eberbach, 2012). PBL has been increasingly making its way from medicine into engineering, science, computer, and many other domains in the past decades

However, the PBL practice is still far from widespread. One of serious impediments to PBL's diffusion in education is that teachers, with few exceptions, do not have the expertise to transform a lecture-driven course into a problem-driven course because they are well-versed in teaching and lecturing, but have a difficult time changing their role to that of a facilitator who guides students but does not give the answers (Ertmer & Simons, 2006). Further, students are not familiar with this approach and need time to adjust to new kinds of demands such as self-directed inquiry, complex problem solving and teamwork. They need various kinds of support to make such transitions. To address these hurdles, some have looked to technological solutions.

To facilitate PBL, teachers have exploited many software tools such as emails, discussion forums, media-sharing applications, blogs, and wikis. These generic application tools have a primary use to support PBL processes on a certain aspect such as access to resources and collaboration (Kaldoudi et al., 2008; McLoughlin and Lee, 2008; Dirckinck-Holmfeld, 2009). However, they provide insufficient support for teachers systematically organizing and structuring multi-disciplinary / faceted knowledge needed for solving the problem in PBL-infused courses and provide insufficient support for students in collaborative knowledge building in an online or blended PBL environment. In the past decades, some efforts have been made to support collaborative knowledge building in PBL by providing knowledge representation and management tools. In the same line, this paper proposes a problem-oriented knowledge management method and presents an associated, visualized knowledge representation tool to support collaborative construction of multi-disciplinary / faceted knowledge artifacts in a technology-enhanced PBL environment. We argue that such a knowledge management approach is technically feasible and the visualized knowledge representation tool can help students to systematically represent and construct knowledge artifacts at right time in PBL processes.

In the remainder of this paper, we first identify technical requirements through characterizing PBL and discussing related work. Then the problem-oriented knowledge representation and management approach is presented. The next section demonstrates the technical feasibility of this approach by presenting the implementation of a web-based PBL application, in particular, the visualized knowledge representation tool. Finally, it discusses relevant issues and presents conclusive remarks.

2. Technical Requirements to Support the Collaborative Knowledge Building

2.1 Charactering PBL

PBL is an active learning method based on the use of complex, ill-structured problems as a stimulus for collaborative learning (Barrows, 2000). Such problems may not have a single correct answer but require learners to consider and negotiate between alternatives and to provide a reasoned argument to support the solution they generate. The solution and the argument are knowledge artifact in that it involves constructing an explanation. PBL is designed to help students build extensive and flexible knowledge (Hmelo-Silver and Barrows, 2008). Knowledge building is generally viewed as a discursive activity intended to enhance collective understanding (Bereiter, 2002). Students should be responsible for learning what they need to know as they are engaged in generating and evaluating solutions of the problems collaboratively. The responsibility for the success of the effort is shared by the students and teacher instead of being provided by the teacher alone (Scardamalia, 2002). The teacher mainly takes the role of the facilitator who presents the student with a real-world problem. The facilitator is in charge of the smooth movement of the student through the various stages of PBL and monitoring of the group process. This monitoring warrants that all students are involved and encourages them to share their thinking and to comment on each other's thinking (Hmelo-Silver, 2002). In collaborative knowledge building, the group activity is structured so that responsibility for learning is shared, expertise is distributed, and building on each other’s ideas is the norm (Palincsar and Herrenkohl, 2002). Progressive discussion is central to collaborative knowledge building as students create conceptual artifacts

At a typical PBL tutorial process, the learners are firstly presented with an authentic and ill-structured problem without any preparation or study. Then, the learners work in groups to generate ideas about aspects of the problem, to analyze and organize the ideas inductively, to categorize the idea groups to coherent and distinctive characters and to create a logical and thematic basis for problem solving and learning process. They identify the unknown and unclear issues, formulate learning needs, identify sources for knowledge acquisition, and check learning objectives and action plan for knowledge acquisition. Knowledge acquisition is the phase of self-directed information acquiring. The skills and knowledge acquires are then shared among the group members and finally applied back to the problem, to evaluate the quality of learning. The learners' learning in the PBL is summarized and integrated into the learners' existing knowledge and skills to deepen learning.

2.2 Discussing Related Work

In PBL students should be active participants in identifying knowledge problems and collectively improving their ideas. It makes the student's thinking visible and open for discussion. The role of the teacher is to model their thinking processes and help students appropriate the social and epistemic rules for productive discourse (Duschl & Osborne, 2002). Cornelius and Herrenkohl (2004) demonstrated that various tools, such as visual representations, encouraged discussion around scientific ideas and theories.

The shared knowledge artifact is an important part of the learning context in collaborative learning processes. In conventional learning environments, the shared artifact is usually carried on paper or blackboards and is recorded in the form of text, tables, or diagrams, etc. The learners have rich communication channels with which to exchange their ideas and negotiate knowledge face-to-face. However, in virtual learning environments, because of the distribution of learners in time and space, and the limitation of the communication channels, exchange of ideas mainly relies on the shared knowledge artifact being represented in an electronic form. The basic requirement to support exchange of knowledge in such virtual learning environments is to provide a shared workspace. Within the shared workspace learners can access and construct shared knowledge artifact. However, if the collection of information is ill-organized, then shared workspace makes it difficult for learners to systematically represent their knowledge, and to manage shared knowledge artifacts.

In order to systematically support online PBL, some PBL dedicated applications such as McBAGEL (Guzdial 1996) and STELLAR (Hmelo-Silver, et al. 2009) have been developed. These applications support collaborative knowledge building by providing a shared PBL-specific whiteboard. For example, McGABEL has a PBL whiteboard that helps scaffold students' problem solving via a PBL process. The whiteboard provides a shared workspace that is split in to four columns. Through the students in small groups can access to the relevant information regarding the problem they need to solve by clicking on the button labeled "problem information". The students identify data relevant to the problem from the information provided and record them in the "facts" column. Also possible solutions are recorded in the "ideas" column. The students during the process what they need to know and record them in the "learning issues" column and the action to take in order to resolve these knowledge deficiencies are enter in the "action plan" column. Besides the shared workspace, McGABEL also provide buttons at the bottom of the screen access to different tools (such as digital libraries) that the students will required solving the problem.

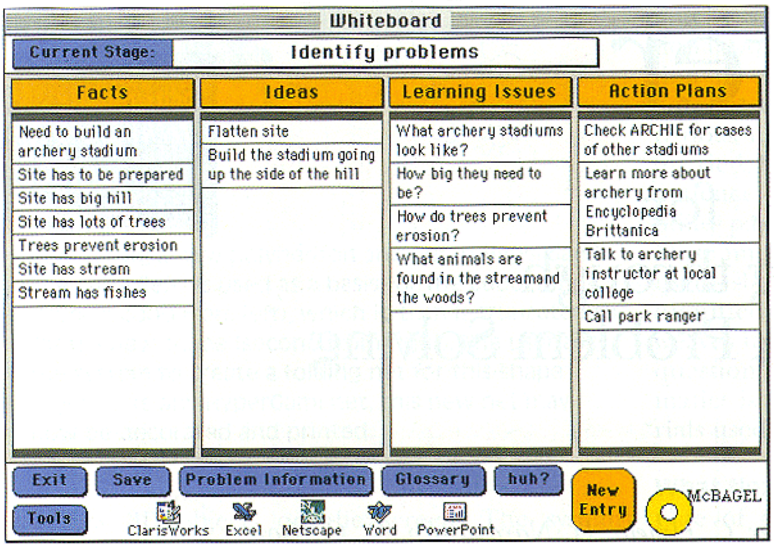

Figure 1. McGABEL's Whiteboard with Four Columns

However， the shared workspace provided by the PBL whiteboard like McGABEL whiteboard just permits collaborative recording of main ideas but it does not support to represent and show relationship between these ideas. All ideas can only be represented in the form of text. Also does not allow additional information to be bounded to these main ideas or support activity-based discussions or instant messaging. Although many PBL applications have been developed, the column-based PBL-whiteboard hasn't been improved.

2.3 Identifying Technical Requirements

Though characterizing PBL and discussing related work, we can identify technical requirements to support collaborative knowledge building using a shared workspace. It has been suggested that visually structured knowledge representation methods can be used to organize the information contained in shared knowledge artifacts (Hmelo-Silver and Barrows, 2008). Such visually structured knowledge representation methods should help the learners to represent and reflect on their knowledge, to detect points at which their individual knowledge structures are in conflict, and thereby to pursue common understanding and to build a coherent representation of their common knowledge. In comparison with existing PBL whiteboard, the following requirements to develop a visually structured knowledge representation are identified:

Categorizing knowledge artifacts: In PBL students define problems, identify learning issues, collect information, develop hypotheses and apply strong deductive reasoning to the problem at hand. When the students express their knowledge, they need to express why they are including a new piece of information, and what role this information plays within the overall shared knowledge structure. It should be possible to clarify the contribution which a particular piece of information makes to the overall task. This could be achieved by allowing the learner to label their contributions. In existing PBL-specific whiteboard, just three or four primary types of information such as fact, ideas, learning issues and actions are explicitly listed. However, more types of information such as hypotheses, argumentation, evidences, solutions, evaluation, and reflection are generated and used in PBL. It is required to distinguish different types of knowledge artifacts that help students think aloud and understand easily.

Expressing Relationships: In order to further support the learners to describe the role which each piece of information plays in the whole, we need to allow them to build and label relationships between their contributions. In traditional subject-based learning, the knowledge is well-structured and can be easily represented by using concept-mapping tool because the relations between concepts can be directly represented according to the disciplinary knowledge logics. However, the knowledge learned in PBL is multi-disciplinary / faceted. It is required to develop a method and a tool to organize multi-disciplinary / faceted knowledge.

Supporting access and search of knowledge artifacts: It is required to provide students an overall picture of the shared information which has been contributed by the group members. In our view, this overview should also provide the access point from which learners can reach all parts of the information carried in the shared artifact. It is required to support students to search for information easily in the shared knowledge artifact. For example, they might search for the most recently contributed knowledge artifacts, for certain types of knowledge artifacts, or for those created by a person. In PBL, for example, learners might want to view their learning goals in isolation, or simply to view problems and their solutions. All other information could then be hidden from view. In this way the group could focus on particular aspects of their task without interference from the wider context.

Supporting collaboration: The tool should provide a visual indication of the points at which conflict occurs. When exploring the information space, learners can then easily see points at which they should further discuss with other learners, or gather more information. The tool should foster to discuss and comment on each others' contributions. It is required to support students to show how additional information, which perhaps describes the wider context or gives more detail, relates to the information displayed on the shared knowledge artifact such as who knows or doesn't know a learning issue. The recorded knowledge artifacts could serve as a source of information for other interested learners who may not have originally contributed to the shared artifact. The information in the shared artifact should be stored persistently, and consideration should be given to the level of accessibility given to other interested parties.

3. A Problem-oriented Approach to Represent and Manage Knowledge

This section presents our problem-oriented knowledge representation and management approach that is based on the ideas of concept map. A concept map is a graphical tool for organizing and representing knowledge (Moon et al., 2011). It is a way of capturing understanding of a topic in a way that shows how concepts are related and helps people create mental models and visualize knowledge. They include concepts, usually enclosed in circles or boxes, and relationships between concepts indicated by a connecting line linking two concepts. Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement. For example, a proposition in a concept map can be represented as two concepts "Moon" and "Earth" connected by a labeled link "move-around". Because concept maps are constructed to reflect organization of the declarative memory system, they facilitate sense-making and meaningful learning. As Novak & Cańas (2006) pointed out, a meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures. Concept maps are widely used in education such as capturing, realizing or formalizing knowledge, collaborative knowledge modeling, transferring expert knowledge, facilitating the creation of shared vision and shared understanding within a team or organization, communicating complex ideas and arguments, and assessing learner understanding.

However, the concept map provides insufficient support for organizing information and supporting collaborative knowledge building required by PBL. We are particularly concerned to support situations in which the content domain is ill-structured and covers more than one topic in PBL. This is typically the case when learning topics arise on the basis of multi-disciplinary / faceted need, rather than within more traditional subject-based contexts. In such more traditional learning situations, the content of the knowledge domain itself can be used to structure knowledge, and therefore naturally provides the representational means to present this knowledge piece by piece to the learner. In contrast, the knowledge handled in PBL is ill-structured. We therefore cannot use the content as the basis on which to organize the shared knowledge. We choose instead to organize the shared knowledge on the basis of learning activities, such as defining problem statement, identifying learning issues, setting learning goals, collecting learning resources, reasoning, or generating solution. For each type of learning activity, we propose that specific node and link types and associated operations can be designed which will appropriately support and restrict the construction of a set of networked knowledge nodes. In PBL students construct and represent knowledge artifacts around the driving problem. We call this method a problem-oriented approach to represent and manage knowledge. The following paragraphs present how the identified requirements can be met by adopting the problem-oriented knowledge representation and management approach.

Firstly, we can define knowledge artifact types for organizing information generated and used in PBL. The most important type of knowledge artifacts is *problem* that the students should identify, analyze, and formulate at the beginning of the whole learning process. The facilitator provides *problem triggers*, which are used to describe and understand the problem. It may be presented as case/scenario/phenomena/situation. For each problem students can identify *learning issues* and define *actions*. While performing an *action*, students can propose *hypothesis*, provide *argument* with *evidence*, identify and collect *information*. They can provide *explanation* and generate *solution* to solve the problem. Furthermore, students can generate *evaluation* and *reflection* artifact. They can also apply acquired knowledge to develop *products*, provide *recommendations*, and indicate *predictions*. Some types of nodes have content. The content of a node can be represented in a form of media such as text, image, audio, or video.

Secondly, we enable teachers and students to explicitly represent relationships between these typed knowledge artifacts using typed links. As shown in Figure 1, for example, a *problem* may be a sub-problem of a big problem. A *problem trigger* informs about *problem*. A *learning issue* normally respect to one or more (sub-) *problems*. An *action* is arranged to learn one or more *learning issues*. A chunk of *information* concerns one or more *learning issues*. A *hypothesis* responds to a *problem* and a *solution* solves a *problem*. *Argument* and *evidence* can be connected to a *hypothesis* for supporting/countering it. Students can create an *evaluation* node or a *reflection* node that is about an addressed *problem*, an identified *learning issue*, or a generated *solution*.

Thirdly, teachers and students can organize multi-disciplinary / faceted knowledge as a set of typed nodes and links. From the perspective of disciplinary such a network of knowledge artifacts may be not all directly related according to knowledge logics. However, they represent various facets of a problem. The teacher can prepare and organize knowledge to be taught as a network of knowledge artifacts. However, the teacher does not present such a network of knowledge artifacts directly to students in a PBL course. Instead students will be guided and facilitated to collaboratively construct a network of knowledge artifacts themselves. The network provides a workspace for constructing, exchanging, and using knowledge artifacts and acts as a group memory of the shared knowledge. We develop a function to detect what is missing in students' network through comparing it with teacher's network. We can pre-define questions and hints. An example of question is "do you know the temperature on the Moon?" An example of hint is "you forget to arrange an action to learn the issue 'Day-night cycle'." In online PBL such questions and hints can be presented to students based on the detected missing artifacts when students need help and the teacher is not available. Students can also search knowledge artifacts created by the students of other group taking the same PBL unit. The retrieval constraints can be specified in terms of artifact types, topics, creators, creation time, and so on. The results of retrieval can be displayed accordingly, for example, only the target information or those with associated information as well.

Finally, while a node in a concept map is just used to represent a concept, a typed node in the network of knowledge artifacts is allowed to operate for fostering collaboration. Students can operate on a node according to its type. For example, each student can express personal status/opinion about the content of a knowledge artifact (e.g., a *learning issue* or *hypothesis*) such as who knows/agrees or doesn't know/agree a *learning issue/hypothesis*. The node provides a visual indication of the points at which conflict occurs. When exploring the network of knowledge artifacts, students can then easily see points at which they should further discuss with other students, or gather more information. Artifact-bound communication mechanism can foster to discuss and comment on each others' contributions. Additional information of an artifact node describes the wider context or gives more detail, relates to the information displayed on the shared knowledge artifact. The recorded knowledge artifacts can serve as a source of information for other interested students who may not have originally contributed to the shared artifact. The additional information in the shared artifact can be stored persistently, and consideration is given to the level of accessibility given to other interested students.

4. A Combined Use of the Problem-oriented Knowledge Representation Method and a PBL scripting Language to Support Collaborative Knowledge Building

The problem-oriented knowledge representation method described above specifies how the multi-disciplinary knowledge artifacts with various types can be organized around a problem. However, when a group of students collaboratively construct a shared network of knowledge artifacts in a computer-supported learning environment, a computational mechanism is needed to orchestrate students' contributions in a PBL process. Through analyzing the commonalities and differences of the various PBL models and various PBL practices from the process modeling perspective, we developed a PBL scripting language. Rather than providing generic and abstract constructs in a learning design language like IMS-LD (Koper and Tattersall, 2005; Koper and Miao, 2008) and CSCL scripting language (Miao, et al. 2007), the PBL scripting language provides PBL-specific constructs. The teachers can easily understand and use the PBL scripting language because the vocabularies and syntax are similar to those they often use to describe PBL process (Miao et al. 2014). With this language the teachers can represent a PBL process as a computational description of an online PBL course or lesson, called a PBL script. The high-level constructs of the PBL scripting language are PBL processes such as *Preparation, Problem Engagement, Problem Definition, Idea Generation, Learning Issue Identification, Plan, Investigation, Reasoning, Information Sharing, Problem Resolution, Application, Report, Evaluation, Reflection, Report,* and *Application*. Each of the processes is defined in terms of properties such as title, description, goal, outcomes, and activities that may be performed to achieve certain outcomes in the process. A PBL script consists of a sequence of phases. Each phase can be defined by selecting one or more processes. The number of phases and their sequence can be decided by the teacher. As a consequence, various PBL strategies can be designed by making different choices and combinations and sequencing phases differently. As mentioned above, each process has a list of possible activities. Some activities within the selected processes in the phase can be selected as work steps to form a workflow. For example, if a phase has been defined by choosing the *Learning Issue Identification* process, the activities (e.g., *Identify learning issue, Organize learning issue, Formulate learning issue, Relate learning issue to problem,* and *Identify knowledge need)* specified in this process can be selected to define an activity sequence as internal structure of the phase. The PBL scripting language enables to represent an activity through assigning actors (e.g., a facilitator, a student, or a group of students) and specifying allowed operations on certain knowledge artifacts. Thus, a PBL script described in the PBL scripting language can be regarded as a formal model specifying a PBL strategy. The formal model can be used to scaffold and orchestrate a collaborative learning process at run-time through specifying the access control rights.

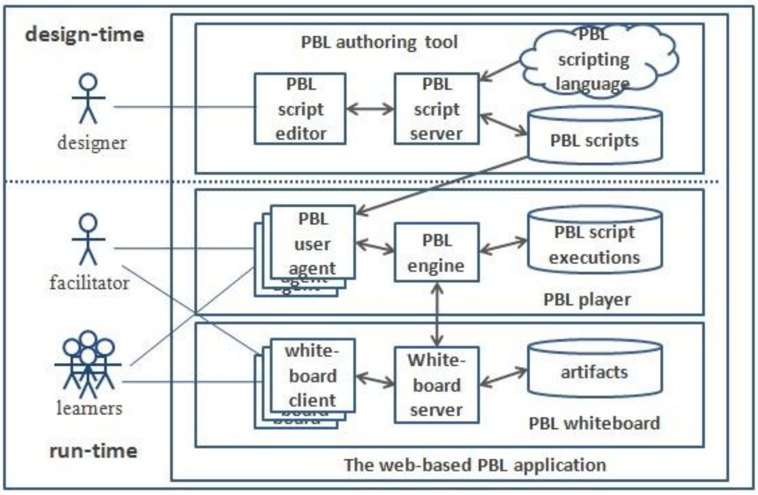

Figure 2: The system architecture of the web-based PBL application

We have implemented a web-based PBL application. It consists of a PBL authoring tool, a PBL player, and a PBL whiteboard. Each tool is implemented in three-layer architecture. We use JavaScript for programming both at client side and at server side (Node.js), together with MongoDB for data persistence and JSON for data exchange (Wang et. al. 2014). As shown in Figure 2, the PBL authoring tool is used in design-time to specify a PBL script representing in the PBL scripting language. A PBL script is a formal model articulating phases, activities and their sequences, the roles and their assignments to the activities, and the way to accomplish each activity. In run-time, the teacher can select and instantiate a PBL script as an execution of the PBL script using the PBL user agent and then the engine in the server site will manage and enact the execution of the PBL script. The learners of the PBL course will be informed when the execution starts. When a participant joins the PBL course through the PBL user agent, a PBL whiteboard will be invoked for her or him by the PBL engine.

Using the PBL whiteboard client, the participant can access learning resources, communicate with other participants, and individually or collaboratively create and manipulate knowledge artifacts following the PBL script. As shown in Figure 3, a screenshot shows the user interface of the PBL whiteboard client. This user interface consists of three parts: the communication panel (on the left), the work space (in the middle), and the property edit panel (on the right). The student is currently identifying learning issues relevant to a problem "how to live and work on the moon" that has been decomposed into several sub-problems. The topics around this problem may cover the fields of physics, biology, astronomy, sociology, and so on. Currently, some learning issues such as "power" and "Moonquakes" have been identified. She/he can create new learning issue artifact through dragging an artifact icon in the construct field (up-left area in the work space) and dropping it in the work space. A dialog window will pop up and the user will be asked to choose the type of artifact and input the title of the artifact. After the dialog is finished, a node representing the artifact will appear on the whiteboard. The user can choose the media type to describe the content of the artifact or use text as the default media type. In the case captured in this screenshot, the student created and edited a learning issue "Temperature". She/he can set values of properties of the learning issue by using the property edit panel. An arrow can be created to connect two artifact nodes with a label to indicate the relationship of two artifacts, for example, an arrow labeled "respect to" links two artifacts: an issue "Thermal Management" and a sub-problem "Temperature". For certain types of nodes, further attributes can be assigned to the nodes, which allow the student to indicate how confident they are in the contents of the node, and the extent to which they agree or disagree with it. Users express their agreement or disagreement with the contents of a node by selecting 'agree' or 'disagree' from the pop-up menu. The degree of confidence which learners have in their knowledge about the content of a node is also expressed via the pop-up menu options, specifically 'I know' and 'I don't know'. Using the communication panel, the user can view the state of other users and initiate communication by invoking a chat tool or sending a piece of message. It is important to note that the user interface (UI) of the whiteboard client is, rather than totally hard-coded, configurable. It can adapt to the role of the user, the types of current phase and activity, and the work mode or policy. For example, a role and its access rights can be defined in the PBL script. In the run-time, the PBL engine will send to each whiteboard client the information about the role of the owner of this whiteboard client. The whiteboard client will adjust UI to the role of the user according to the definition in the PBL script. For example, when the user is currently in the phase "*Learning Issue Identification*", only the artifact with the type of *learning issue* can be created in this situation. If more than one type of artifacts can be created, a popped-up dialog just shows a list of appropriate types according to the specification of the PBL scripting language. Using such a restriction the user will be guided and constrained to do right job in this phase. In particular, the configuration of the UI is determined by high-level abstraction. Whether a user can delete a node is not controlled directly at a low level. The whiteboard client gets the current work mode from the engine and adjusts the UI according to the interpretation of the defined work mode. For example, when brainstorming, no one can delete an artifact node created by others. If shifting to organizing, the whiteboard client enables certain users to delete artifact nodes according to the specification in the PBL script.

In summary, through a combined use of the problem-oriented knowledge representation method and the PBL script, participants can be scaffold to construct a network of knowledge artifacts as they progress through their various activities (through the availability of appropriate node types, link types and operations). Essentially, we have supported them to organize their knowledge on the basis their activities.

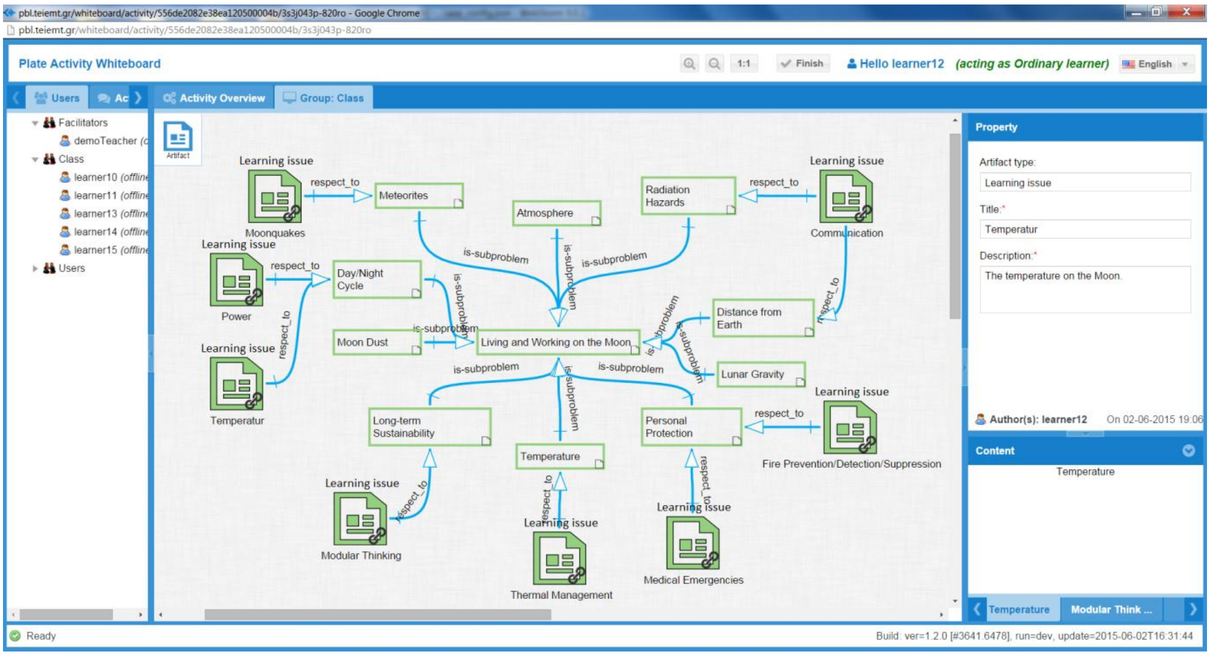

Figure 3: a screenshot of our PBL Whiteboard

5. Discussion and Conclusions

In this paper, we propose a problem-oriented knowledge representation and management method in PBL for supporting collaborative knowledge building. When students conduct an online PBL unit by taking this method, a network of visually structured, shared knowledge artifacts can serve as a medium for collaborative knowledge building and provide the role of a group memory. This visualized knowledge representation method is based on concept maps. In concept maps, the nodes are used to present concepts or ideas in a topic (e.g. "dog" and "animal") and they are linked with a content-based relation (e.g. is_a_kind_of) as a formal or semi-formal diagram. This in part satisfies the requirements for the representation of knowledge. However, the content-based approach is not suitable for representing ill-structured knowledge, because for ill-structured domains also the knowledge structure would be ill-structured. In additional, concept maps have not been used so far to indicate points of confident/conflict and are not allowed to do any operations except for creation and deletion. In PBL, knowledge related to a real-world problem is ill-structured from the perspective of content. By choosing an activity-based approach, rather than the content-based approaches, we have begun to address the question of how to represent and manage ill-structured knowledge with additional information of an artifact node and to enable artifact-specific operations for fostering collaborative knowledge building. Moreover, through a combined use of the problem-oriented knowledge representation method and the PBL script, the access rights to the shared knowledge artifacts will be specified in a systematic manner. As a consequence, the functions and the user interfaces of our PBL whiteboard can be adjusted according to the role of the users, the phases and the activities at run-time. The participants will be guided and constrained to do right job in the discourse of collaborative knowledge building as they progress through various activities.

So far we have evaluated the PBL authoring tool and the results of the data analysis reveal that teachers have positive responses regarding the usefulness and easy to use of the tool (Miao et al. 2014). Recently we have finished the development of the PBL player and the PBL whiteboard and intensively tested them on the aspects of the functions. The test results demonstrated the usability of the tools and the feasibility of the technical approach. We are conducting serious evaluations to investigate the usefulness of the whole PBL application in real-world setting. We will report the evaluation results in the near future.

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