Songklanakarin J. Sci. Technol.
43 (6), 1772-1778, Nov. - Dec. 2021

http://www.sjst.psu.ac.th

Original Article

Knowledge modelling in teaching and learning with technology support♣

Athitaya Nitchot[1*], Lester Gilbert[2], and Wiphada Wettayaprasit[1]

[1] *Prince of Songkla University International College Hatyai Campus, Prince of Songkla University, Hat Yai, Songkhla, 90110 Thailand*

[2] *School of Electronics and Computer Science, University of Southampton, Southampton, United Kingdom*

[3] *Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla, 90110 Thailand*

Received: 1 December 2020; Revised: 12 July 2021; Accepted: 23 July 2021

Abstract

A teaching and learning environment contains data representations of information and knowledge, these being resources, materials, and other artefacts. We present a pedagogically informed model which represents the learner's knowledge, being their capability with respect to some subject matter and context, and outline an implementation of the model in a prototype knowledge mapping tool. Recent results have shown satisfaction and learning improvements. In the paper we discuss the extension of knowledge mapping to include contextual elements and the extension of the prototype tool to include self-assessment and learner analytics.

Keywords: knowledge representation, knowledge map, learner competence, technology-enhance learning

1. Introduction

The terms virtual learning environment (VLE) and managed learning environment (MLE) describe a computer-supported environment with tools for distance learning or even conventional classroom learning. VLE and MLE have been applied within many educational domains, for example Stricker, Weibel, & Wissmath (2011) used a virtual learning environment (VLE) as Internet based self-assessment tool within a university course under psychology subject domain. The purpose of this VLE was to enhance students' learning process. Barker & Gossman (2013) investigated the impact of using VLE as Moodle on learning and reported that the use of Moodle gives improvement in learning and motivation and enhances learning. Phungsuk, Viriyavejakul, & Ratanaolarn (2017) developed a problem-based learning model using VLE for Thai undergraduate students in Photography class. They concluded that such model supports and enhances students' learning, achievement and problem skills. Gallagher (2004) built an interactive multimedia as extensive creation of a MLE based on WebCT for student, lecturer and institution. The results showed that WebCT (WEB-based Course development Tools) enriched the learning process and promised cost efficiencies. However, conventional or distance learning in computer-supported environment must be integrated with a pedagogical approach, so the learners can fully benefit from the learning facilities and features. A teaching and learning situation contains data representations of information and knowledge, typically provided by an agent taking a teaching role, and processed by agents taking a learning role.

A preliminary study asked teachers' opinions in designing knowledge maps, and showed that most teachers used mind mapping or concept mapping of subject matter. Concept Mappings are used widely among all map creators to express their understanding of all knowledge domains (Cañas, Novak, & Reiska, 2015). Cañas *et al.* (2015) defined a

♣Peer-reviewed paper selected from The 9th International Conference on Engineering and Technology (ICET-2021)
*Corresponding author
Email address: athitaya.n@psu.ac.th

concept mapping as a graphical representation of a set of concepts enclosed with circle or rectangle and relationships between concepts indicated by connecting lines linking each a pair of concepts. Concept mapping has been used within many studies, for example, Kaddoura, Van-Dyke, & Yang (2016) used concept mapping as an educational method to promote critical thinking skills in nursing students, and they concluded that students who used concept mapping performed much better on the Health Education Systems. Even a mind mapping, which has similar representation as concept mapping, has been used within the educational or training domain. For example, Zubaidah, Fuad, Mahanal, & Suarsini (2017) used mind mapping to train students' creative thinking skills within different science learning models and they concluded that the students who used such mapping could show the highest creative thinking skills. In our research, we propose a knowledge map representation which comprises a competence map of nodes tagged with one or more context and/or performance elements. The precedence relationships in the map express prerequisites – successful study of a parent node requires prerequisite knowledge of the child node(s).

'Mytelemap' is a prototype tool developed to support authoring and using knowledge maps. A key feature of the tool is its provision of personalized links to study materials according to the node selected by the learner. The paper describes the theoretical basis of pedagogically-informed knowledge mapping and the tool development and experimental validation, and discusses some features for future development.

2. Environment, Teaching and Learning

A teaching and learning environment can be: a technology-based virtual learning environment (VLE), managed learning environment (MLE), or similar; simply based on postal, telephone, or broadcasting services for distance learning; or conventional classrooms and laboratories. Dillenbourg, Schneider, and Synteta (2002) defined a VLE as a range of systems that comprise the features of a designed information space and a social space for learners and teachers. An MLE combines a VLE with a management system to hold extended information about participants and e-moderators (igi-global.com 2020). However, to use or rely on a VLE or MLE does not necessarily lead to effective learning. In common with conventional or distance learning environments, VLEs and MLEs must be integrated with an appropriate pedagogical approach to gain learning benefits from their facilities and features.

Communication and exchanges between teacher and learner are mediated within the teaching and learning environment, and this involves the communication and exchange of data (only). Because we regard information and knowledge as personal constructs, we consider that these cannot be externally stored and cannot be transmitted. On the other hand, representations of information and knowledge can be externally stored, processed, and transmitted, because such representations are forms of data. It is these representations which are present in the environment and exchanged between teacher and learner, and it is these representations which need to be pedagogically informed. Figure 1 illustrates the learner and teacher embedded in an environment which contains data

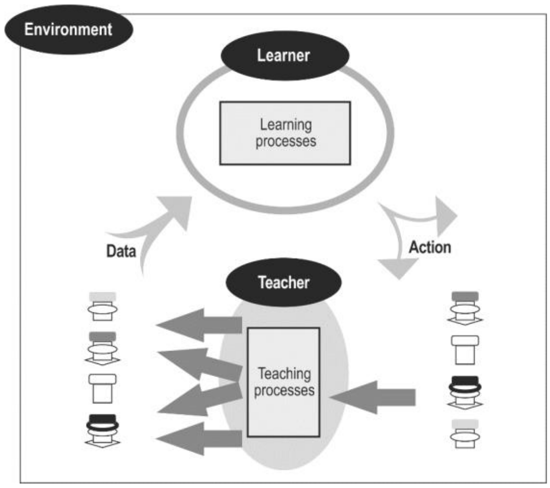

Figure 1. The abstract teaching and learning situation

representations of information and knowledge, being resources, materials, and other artefacts. These representations are the results of actions and activities by teachers and learners.

The teaching processes of Figure 1 are shown as four fundamental activities in Figure 2 in conventional order: tell/show, ask, judge, and give feedback. Usually, the teacher first tells, shows, or explains using teaching materials and resources such as lecturer notes, slides, videos, web links, or demonstrations. Then the teacher may ask questions of the learner, either informally during a pedagogical conversation (Laurillard, 1993), or somewhat more formally as a formative or summative assessment. The learner's responses are judged and evaluated, and the teacher then gives feedback in a communication to the learner.

The learning processes of Figure 1 are located within a learning and teaching environment which contains data that the learner may (or may not) process, and into which the learner may (or may not) place response artefacts. The relevant data in the environment is usually placed there by teaching activities, primarily tell and show resources, but also including interactional, assessment, and feedback resources. Additionally, the learner may find other relevant data in library or web resources. Learner response artefacts placed in the environment are themselves data items (such as essays, reports, exercises, etc.) which are usually processed by the "judge" teaching activity, conventionally by teachers, but also by others such as colleagues and mentors, and possibly by computational agents.

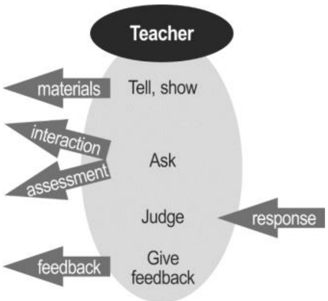

Figure 2. The abstract process model for teaching

3. Representation of Knowledge in Learning

Competence has a number of definitions (Sampson & Fytros, 2008). It can refer to the knowledge, skills, traits, attitudes, self-concepts, values, or motives directly related to job performance or important life outcomes (McClelland, 1973), or the combination of skills, abilities, and knowledge needed to perform a specific task (Voorhees, 2001). In our research, a competence refers to a learner's capability with some associated subject matter. Normally, in a teaching and learning situation, we want to ensure that the lesson or module activities are consistent with the competence we seek in the learner. However, we note that these activities and the competences they target lack explicit identification of contextual factors (such as tools, resources, and environments) which are of central importance. For example, being able to sculpt a human head using clay, and being able to sculpt a human head using computer software, entail profoundly different teaching and learning activities and prerequisite knowledge, yet could appear to be the same competence if the contextual elements were not mentioned. We also note the general lack of explicit identification of performance elements (proficiency, evidence) in target competences. An abstract knowledge model is proposed in Figure 3, where this paper focusses regarding its context and competence components.

We broadly follow the characterization of subject matter types given by Merrill (Merrill, 2000), and of capability types given by Merrill and Bloom (Bloom, 1956). It may be useful to recall that the model regards a "competence" as the combination of a "capability" with given "subject matter". Capabilities are verbs, and these are often referred to as "learned capability verbs" to emphasize their use in teaching and learning contexts. Following Bloom, we identify three domains of capability being "cognitive", "psychomotor", and "affective", noting that the model can accommodate other domains as may be required in a particular situation, such as "social" and "aesthetic". This approach is illustrated in Figure 4.

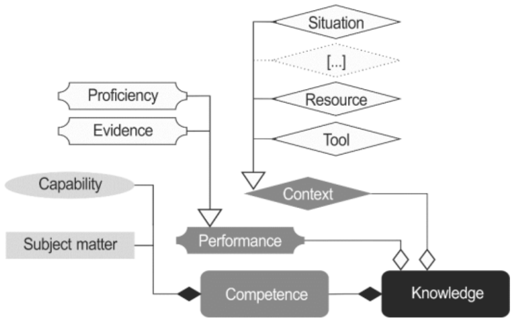

Figure 3. An abstract knowledge model

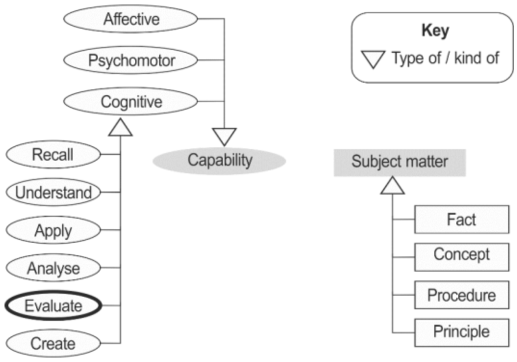

Figure 4. Capability and subject matter in the knowledge model

4. Subject Matter, Competence, Knowledge Map and Technology Support

4.1 Subject matter, competence, and knowledge maps

In our research, we are interested in expressing knowledge, contextualized competence, as a map or graph. A preliminary study asked teachers' opinions in designing knowledge maps. Most teachers used mind mapping for subject matter (Merchie & Van Keer, 2012) and the idea of constructing a knowledge map was rather new to them.

In a content map, a node represents an item of subject matter. Directed links between nodes represent precedence relationships, where a child node refers to an item which a learner should first master before studying the parent item. Such a map is a precedence graph, a type of acyclic directed graph. A competence map arises where subject matter nodes are tagged with one or more relevant capabilities. The precedence relationships thus become enabling relationships – in order to be able to demonstrate the competence associated with a parent node, a learner needs to be able to demonstrate the competence identified by the child node(s).

Finally, a knowledge map comprises a competence map where nodes are tagged with one or more contexts and/or performance elements. The precedence relationships are usually expressed as prerequisites – in order to undertake study of a parent node, knowledge of the child node(s) is prerequisite. The knowledge map representation is shown in Figure 5.

Figure 6 illustrates a sample knowledge map in the domain of 3D modelling. The parent node comprises subject matter of 'human head model', capability to 'sculpt', and two contexts, one of 'using computer software' and the other of 'using clay'. One prerequisite node identifies 'polygon model' of subject matter, the other 'clay composition'.

Another example of a knowledge map in the computer programming domain is illustrated in Figure 7. The subject matter comprises 'programming fundamentals', 'programming variables', and 'programming data types'. Two capabilities for programming variables are identified, 'define' and 'write', and each capability is annotated with two contexts. For the 'define' capability, the contexts identify the tools that can be employed, 'paper-based' and 'computer-based'. For the 'write' capability, the contexts identify the languages involved in programming the variables, in this case either 'C#' or 'Python'.

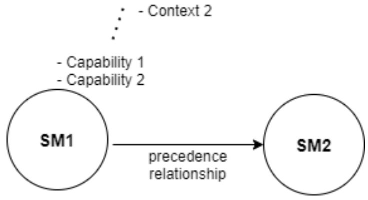

Figure 5. Knowledge map representation (SM = subject matter)

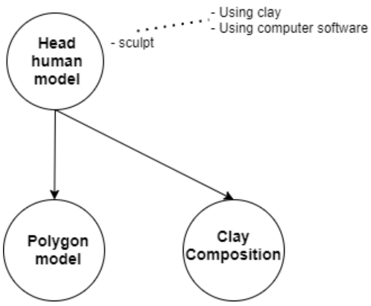

Figure 6. Sample knowledge map under 3d modelling domain

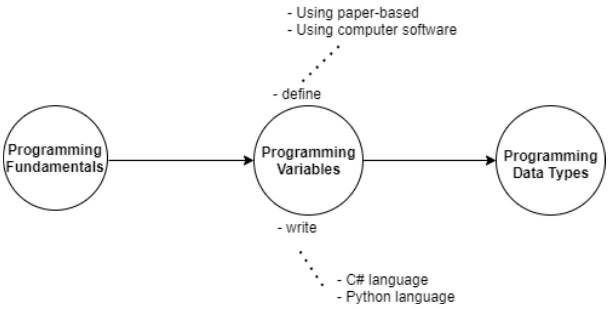

Figure 7. Sample knowledge map under computer programming domain

4.2 Mytelemap and previous experiments

From the representation of knowledge as a knowledge map as proposed in our research, a prototype web-based tool called Mytelemap was developed to support users constructing subject matter, competence, and knowledge maps. The details of users, maps, learning repositories, and usage behaviors are stored within a database. Graphviz (Ellson, Gansner, Koutsofios, North, & Woodhull, 2004) is implemented within Mytelemap to provide graphical drawing tools. Figure 8 shows a sample subject matter map built in Mytelemap. Each node represents one subject matter item and an arrow indicates a parent-child relationship.

The first prototype showed web links generated by a call to the Google API when a subject matter node was selected.

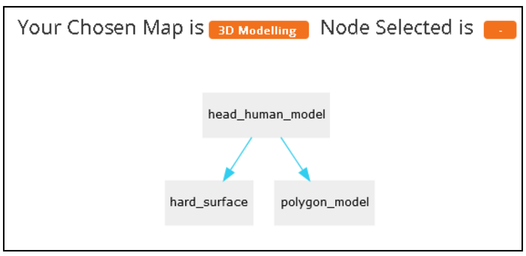

Figure 8. Sample of subject matter map built in mytelemap

We perform two studies on the quantitative and qualitative evaluation of the tool used. First study explored expert and learner ratings of the prototype at the reaction level (Nitchot, Wettayaprasit, & Gilbert, 2019). 5-point Likert scale questionnaire was used to ask experts to give a rating of knowledge map and systems features. The results showed that the mean ratings for the tool in all dependent variables (clarity of node and structure appearance, understanding of design of the structures, and satisfaction on a wide range of types of materials) were significantly higher than 3 ($p < 0.007$) which is the middle or 'neutral' option. Second study compared achievement of learners using Mytelemap with using a general search engine (Google) during self-study. The results showed higher learning achievement when Mytelemap (mean of pre-test score = 3.9 and mean of post-test score = 7.5) was used, where the mean of pre-test score when using Google is 3.8 and the mean of post-test score is 5.5 (Nitchot, Wettayaprasit, & Gilbert, 2018). In addition to this, the opinions from the school teachers were explored and they suggested that designing knowledge structures could be another way of sharing their tacit knowledge with other teachers.

A second prototype introduced capability and context tags to subject matter nodes. Capability tags transform subject matter nodes into competence nodes by providing learning outcomes, and context tags further transform competence nodes into knowledge nodes, as illustrated in Figure 9 and Figure 10.

With this prototype, context elements can be used to filter the web links as shown in Figure 11. In this example, when "computer software" is the context for the node "polygon model", the suggested links contain more relevant content relating to 3D modelling and the use of computer software in sculpting a polygon model.

The second prototype includes a map management dashboard (shown in Figure 12) which allows map creators to modify map details, including map privacy (either to publish or not), and a statistical chart allowing the administrator to monitor uses and views of maps. Additionally, learning resources can be enumerated and their links provided to learners.

5. Conclusions, Future Work, Study Limitations

In this paper, we present a way to represent and map knowledge and demonstrate samples of knowledge mapping in the 3D modelling and computer programming domains. The Mytelemap tool was implemented to support teachers and learners in authoring knowledge maps for self-study. The tool offers study material links according to the node selection of the authored map, both from a user-provided list and from a filtered list of automated Google API search results. The tool provides a visualization of the structure of the knowledge being mapped, and suggests learning paths within the structure.

Order	Learning Outcome	Capability	Context
1	Sculpt polygon model using clay	sculpt	clay
2	sculpt polygon model using computer software	sculpt	computer software

Figure 9. Example learning outcome management of node "Polygon Model"

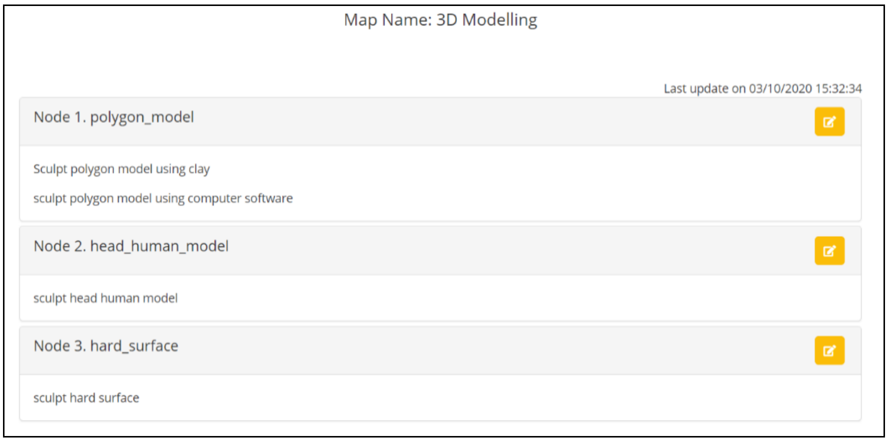

Figure 10. Example learning outcomes for nodes in the map “3D Modelling”

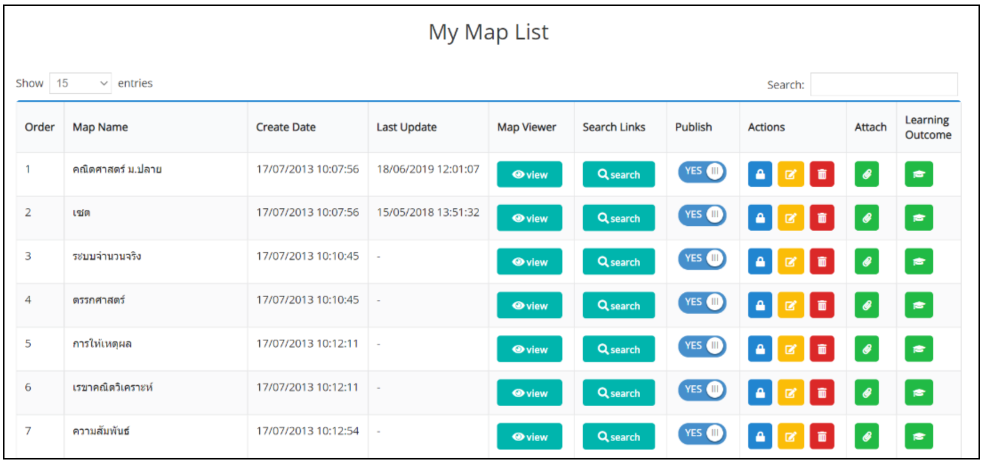

Figure 12. Map management page

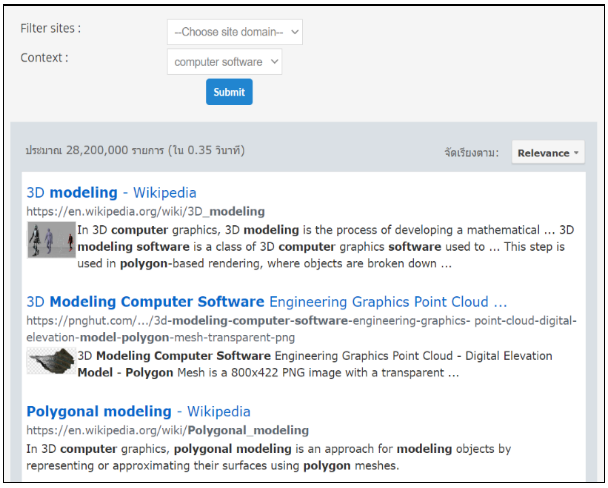

Figure 11. List of study material links under a node “Polygon Model” with filtering context “Computer Software”

5.1 Learner and map analytics

Map usage and learning behavior can be recorded and later analyzed. The next prototype will suggest favorite maps and popular maps as shown in Figure 13. Favorite maps are based on a user setting, and popular maps are suggested based on the counts of access. Records of user access and their history of map activity may support improved suggestions for related maps as is seen in video suggestions and view graphs of YouTube (Baluja *et al.*, 2008).

5.2 Self-assessment

The ‘ask’ teaching activity of the Abstract Process Model for Teaching (Figure 2) will be implemented within Mytelemap. We plan to develop assessment tools for map creators by adding multiple choice questions to subject matter nodes, starting with learner self-assessment. Where a knowledge node identifies a capability, subject matter, and context, a question template will be applied, yielding a multiple-choice question item to self-assess that item of knowledge. Projected future work envisages the development of contextual scenarios which will allow formative and summative multiple-choice question items (examinations) based upon the entire knowledge map.

5.3 Limitations

There are some limitations within our study. Firstly,

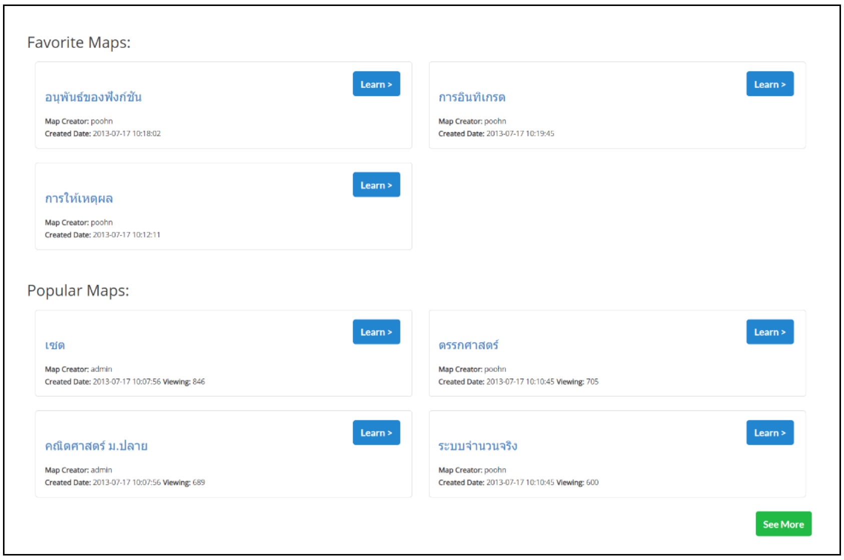

Figure 13. Favorite and popular map page

the experiments conducted were limited to the particular knowledge domains of web technology and of mathematics. Exploration of more domains can be conducted in the future to ensure the applicability and generalizability of knowledge mapping as a learning and teaching tool. Secondly, participants and users were within Thailand's educational system, and application to other cultural contexts and educational systems would be needed to demonstrate generalizability.

Acknowledgements

This research is funded by Thailand Research Fund under contract number MRG6280002.

References

Baluja, S., Seth, R., Sivakumar, D., Jing, Y., Yagnik, J., Kumar, S., . . . Aly, M. (2008). Video suggestion and discovery for youtube: taking random walks through the view graph. *Paper presented at the 17th International Conference on World Wide Web, Beijing, China.* doi:10.1145/1367497.1367618

Barker, J., & Gossman, P. (2013). The learning impact of a virtual learning environment: students' views. *Teacher Education Advancement Network, 5*(2), 19-38.

Bloom, B. S. (1956). *Taxonomy of educational objectives: The classification of educational goals, Handbook 1, Cognitive domain*. New York, NY: McKay.

Cañas, A. J., Novak, J. D., & Reiska, P. (2015). How good is my concept map? Am I a good Cmapper? *An International Journal of Knowledge Management and E-Learning, 7*(1), 6-19.

Dillenbourg, P., Schneider, D., & Synteta, P. (2002). Virtual learning environments. *Paper presented at the 3rd Hellenic Conference Information and Communication Technologies in Education*.

Ellson, J., Gansner, E. R., Koutsofios, E., North, S. C., & Woodhull, G. (2004). Graphviz and dynagraph - static and dynamic graph drawing tools. In M. Junger & P. Mutzel (Eds.), *Graph Drawing Software* (pp. 127-148). Berlin/Heidelberg.

Gallagher, J. (2004). Interactive case study experiences applied to the managed learning environment. *Internet Business Review*, 1.

igi-global.com (2020). What is managed learning environment. Retrieved from https://www.igi-global.com/dictionary/managed-learning-environment/17757

Kaddoura, M., Van-Dyke, O., & Yang, Q. (2016). Impact of a concept map teaching approach on nursing students' critical thinking skills. *Nursing and Health Sciences, 18*(3), 350-354. doi:10.1111/nhs.12277

Laurillard, D. (1993). *Rethinking university teaching: A framework for the effective use of educational technology* (2 ed.). London, England: Routledge.

McClelland, D. C. (1973). Testing for competence rather than for "intelligence". *American Psychologist, 28*, 1-14.

Merchie, E., & Van Keer, H. (2012). Spontaneous mind map use and learning from texts: the role of instruction and student characteristics. *Procedia - Social and Behavioral Sciences, 69*(0), 1387-1394. doi:10.1016/j.sbspro.2012.12.077

Merrill, M. D. (2000). Knowledge objects and mental models. *Paper presented at the International Workshop on Advanced Learning Technologies, 2000 (IWALT 2000).*

Nitchot, A., Wettayaprasit, W., & Gilbert, L. (2018). Personalized learning system for visualizing knowledge structures and recommending study materials links. *E-Learning and Digital Media, 16*(1), 77-91. doi:10.1177/2042753018817615

Nitchot, A., Wettayaprasit, W., & Gilbert, L. (2019). Assistive tool for constructing knowledge structures and suggesting related study materials links. *Education Information Technologies, 24*(1), 219-230.

Phungsuk, R., Viriyavejakul, C., & Ratanaolarn, T. (2017). Development of a problem-based learning model via a virtual learning environment. *Kasetsart Journal of Social Sciences, 38*(3), 297-306. doi:10.1016/j.kjss.2017.01.001

Sampson, D., & Fytros, D. (2008). *Competence models in technology-enhanced competence-based learning, Handbook on Information Technologies for Education and Training*. Berlin, Germany: Spinger Berlin Heidelberg.

Stricker, D., Weibel, D., & Wissmath, B. (2011). Efficient learning using a virtual learning environment in a university class. *Computers and Education, 56*(2), 495-504. doi:10.1016/j.compedu.2010.09.012

Voorhees, R. A. (2001). Competency-Based learning models: A necessary future. *New Directions for Institutional Research, 2001*(110), 5-13.

Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through differentiated science inquiry integrated with mind map. *Journal of Turkish Science Education, 14*(4), 77-91.