ASCILITE 2023

People, Partnerships and Pedagogies

Supporting peer tutoring with graphical organisers and knowledge maps

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This study delves into the realm of learning from tutoring and extends existing research by introducing augmented concept mapping as an innovative strategy to enhance peer learning in preparing for tutoring. The paper provides a concise overview of the current design of pedagogically augmented concept maps and their integration with Semantic Web and derived technologies for the iterative development of knowledge maps. This research represents an ongoing endeavour with the primary objective of developing graphical organisers to support student tutors in designing tutoring plans before actual tutorials in the form of concept maps and knowledge maps. It serves a dual purpose, aiming to facilitate individual tutor learning and promote collective knowledge construction. The main contribution of this presentation lies not only in the potential for synthesising concept mapping and semantic knowledge mapping, but also in the integration of content learning, such as the domain of hydrology in this study, with dialogical tutoring interaction during peer tutoring preparation.

Keywords: Semantic web, concept map, knowledge map, peer tutoring

Introduction

Learning from tutoring, also known as learning by teaching, is a potent educational strategy that improves one's understanding of studied material through the act of teaching it to others. One theory for why this strategy is effective foregrounds the role of generating explanations in the dialogue between tutors and tutees (Roscoe & Chi, 2007). More recently, it has been shown that preparing for tutoring/teaching in and by itself is an effective learning strategy, even in the absence of actual teaching (Fiorella & Mayer, 2013). One explanation for the effectiveness of both learning by teaching and by preparing for teaching is the generative hypothesis: Teaching encourages generative processing that aids the teacher's learning when organizing and elaborating on the material by drawing connections and integrating the content with one's existing knowledge structures (Roscoe & Chi, 2007; Fiorella & Mayer, 2016). This hypothesis also explains the observed benefits of related learning strategies, such as constructing explanatory texts or videos and writing teaching scripts for peer students.

The learning scenario of the study revolves around the interaction between peer tutors and semantic graphical organisers, which encompass knowledge related to the domain of hydrology as well as dialogical tutoring expertise. The knowledge technologies in this study refer to the Semantic Web (SW) and derived technologies, more widely known as Web 3.0 or Web of Data, which is one kind of Artificial Intelligence (AI) technology. These enabling technologies have been in place for a while, though applications in education outside of research are still rare. Building on this, the approach described in this paper employs graphical organisers enhanced by knowledge technologies to support peer tutors in their tutoring planning and peer learning.

To our knowledge, graphical organisers, while widely used for learning, have not been studied in the context of learning from tutoring. Fiorella and Mayer (2013) is the only empirical study found to separate the effects of tutoring preparation and tutoring explanation when accounting for learning gains. They reveal that preparation and actual tutoring may initiate different cognitive processes in learning. The tutoring process stimulates deeper cognitive processing than preparation. However, their preparation phase is limited to learning paper-based multimedia material, without tutoring planning. Indeed, tutoring planning is challenging for novice student tutors. McLuckie and Topping (2004) identify 15 transferable skills for online peer-assisted learning, such as organisation and engagement, cognitive conflict, scaffolding and error management, communication, and affect dimension. The acquisition of these capacities is distributed throughout the entire process of the preparation, tutoring, and reflection phases, providing a theoretical foundation for evaluating tutors' learning.

This paper is reporting on work-in-progress research with the primary goal of utilising the semantic knowledge base to assist peer tutors in designing tutoring plans in the form of concept maps and knowledge maps, with two key objectives: a) Enhancing individual tutor learning by facilitating a shared semantic knowledge base containing domain-specific and tutoring knowledge; and b) Promoting collective knowledge construction by enabling peer tutors to improve tutoring maps through semantic graphical organisers.

Literature review

The Semantic Web standards were developed by the World Wide Web Consortium (W3C, https://www.w3.org/) to make Internet data machine- and human-readable. Currently, the content of the World Wide Web is mainly written in the Hypertext Markup Language (HTML). As an extension of this, the Semantic Web (SW) uses the Resource Description Framework (RDF) and the Web Ontology Language (OWL) to describe meta-data on content, which enables searching for resources in various formats. RDF is a standard model for data interchange on the Web and uses the "subject-predicate-object" triples to name the nodes and links. And OWL is a family of knowledge representation languages for authoring ontologies. While Ontology, in computer and information science, is a data model of showing the properties and relationships of a domain by defining a set of concepts and categories. The SW is the third-generation technology of the Web, launched in 2006. No one knows how long it will take to reach a fully functional Web 3.0 but combined with AI it will provide users with new services and it will revolutionise online learning.

There is plenty of literature on the Semantic applications in learning through our review. Leo et al. (2019) use Ontology to realise the automatic generation of multiple-choice questions and empirically evaluate the effectiveness in a large knowledge base of the medical education scenario. Tzoumpa and Mitropoulos (2020) empirically support the Geometric thinking and learning of middle school students by visualizing Ontology. Wu et al. (2020) develop and evaluate a semantic description and recommendation framework for educational resources that integrates learning diagnosis and instructional reasoning rules. Jeevamol and Renumol (2021) developed an ontology-based content recommendation system for e-learning recommendation systems. Ali and Falakh (2020) developed a self-evaluation system using Ontologies and demonstrated its effectiveness in vocational schools.

Similar to the "node-link-node" structure of RDF, concept maps (CMs) represent relations between concepts in the form of labelled directed graphs and have been already applied and studied in online collaborative learning intelligent tutoring systems. For example, Morita et al. (2021) attempt to integrate knowledge in collaborative CM in the Zoom online learning context. The purpose is to test the editing distance of the individual CM and collaborative CM. The 7 Japanese undergraduates from the Information Science Department were divided into 2 groups to read the paper and design an individual CM based on Japanese Wikipedia. And then design a collaborative CM via Zoom online meeting and then to explain CM to people who have not read the paper. The final step is reporting and scoring. Likewise, Sadita et al. (2020) built a reciprocal kit for collaborative CM. The purpose is to test the effect of reciprocal kit-build on collaborative CM. The participants - undergraduates in Computer Science in Indonesia - designed the individual initial CM, reciprocal kit-build CM, and collaborative CM respectively in the domain of linear algebra. The CM scores and questionnaire feedback show that the CM error decreased. This study contributes to the reciprocal kit-build CM in collaborative learning and proposes the improvement from dyad to group study.

However, there is an interesting gap in the educational literature. While there are plenty of design and design-based methods, there's comparatively little on design specific to technological artefacts (to information systems). The methodological literature that is specific to information systems design research, namely Design science research, says nothing about information systems for learning and training. Also, Design-based research in the learning sciences is usually very hesitant to provide any detail on technology design and development. So, with a few exceptions, one has little to go on in terms of an articulate methodology for learning technology design. In the next sections, thus, we will describe the design-based research approach and technological development of initial concept mapping and iterative knowledge mapping.

Methodology

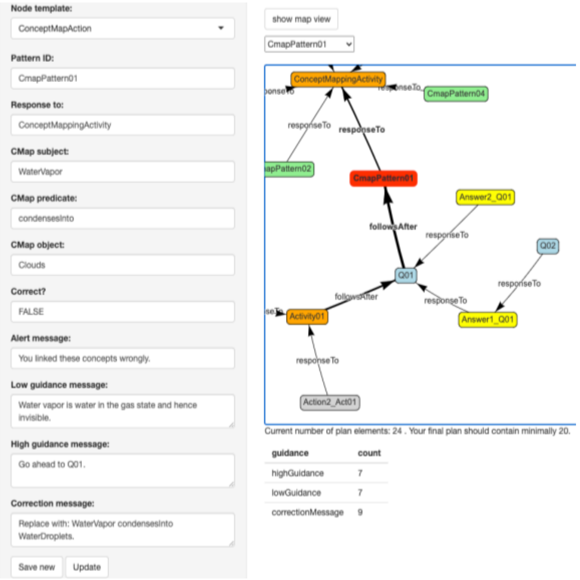
This study employs a Design-Based Research (DBR) approach, which originates in learning science research and serves as a vital bridge between educational theory and practice, uniting not only technology and theory but also design and research.

The specific learning domain under investigation is hydrology. We hypothesise that constructing and reasoning with knowledge maps will lead to even stronger learning effects than constructing concept maps and using them as a graphical organiser. And since knowledge maps in our case will include not only content but also pedagogical knowledge (e.g., questions for the tutee and when to raise them), they should make for a powerful learning tool. The ethical approval was obtained from the University of Sydney Human Research Ethics Committee (Reference No. 2023/111).

Initial design: Augmented concept mapping

CMs have been studied extensively for their function of fostering knowledge exchange between peers (Engelmann & Hesse, 2010) but not for supporting peer tutoring. Aligned with the generative hypothesis, constructing concept maps should lead to deep learning on the tutor's side. Furthermore, concept maps can act as graphical organisers for the tutee and thus should be mutually beneficial. Neither of these two functions has been studied so far.

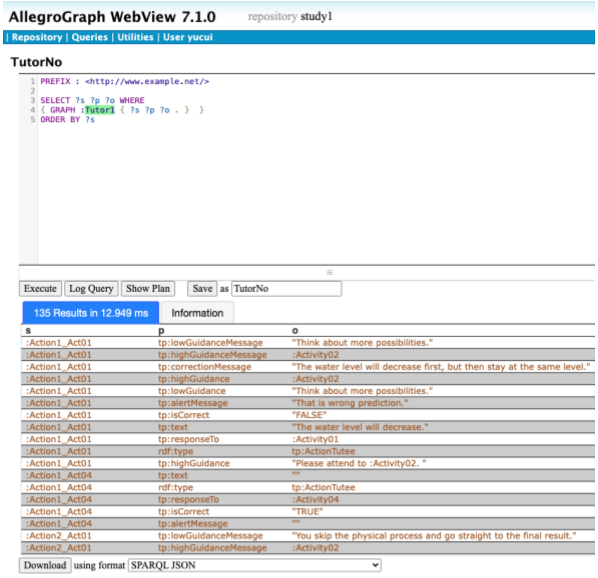
Our study introduces pedagogically augmented concept mapping as a strategy for supporting tutoring lesson plan design. When used as the basis of a tutoring plan, concept maps contain the tutor's understanding of the main relations between domain concepts but may also contain pedagogical information -- they are 'augmented'. For instance, the tutoring map could encode the sequence in which the tutor plans to go through the content with the tutee; questions the tutor plans to ask in connection with certain concepts and relations (nodes and links); problems or misconceptions the tutor expects the tutee may have encountered with certain content.



Node template: ConceptMapAction
Pattern ID: CmapPattern01
Response to: ConceptMappingActivity
CMap subject: WaterVapor
CMap predicate: condensesInto
CMap object: Clouds
Correct? FALSE
Alert message: You linked these concepts wrongly.
Low guidance message: Water vapor is water in the gas state and hence invisible.
High guidance message: Go ahead to Q01.
Correction message: Replace with: WaterVapor condensesInto WaterDroplets.

Current number of plan elements: 24 . Your final plan should contain minimally 20.

guidance	count
highGuidance	7
lowGuidance	7
correctionMessage	9



```
PREFIX : <http://www.example.net/>

SELECT ?s ?p ?o WHERE
{ GRAPH :Tutor1 { ?s ?p ?o . } }
ORDER BY ?s
```

s	p	o
:Action1_Act01	tp:lowGuidanceMessage	"Think about more possibilities."
:Action1_Act01	tp:highGuidanceMessage	:Activity02
:Action1_Act01	tp:correctionMessage	"The water level will decrease first, but then stay at the same level."
:Action1_Act01	tp:highGuidance	:Activity02
:Action1_Act01	tp:lowGuidance	"Think about more possibilities."
:Action1_Act01	tp:alertMessage	"That is wrong prediction."
:Action1_Act01	tp:isCorrect	"FALSE"
:Action1_Act01	tp:text	"The water level will decrease."
:Action1_Act01	tp:responseTo	:Activity01
:Action1_Act01	rdf:type	tp:ActionTutee
:Action1_Act01	tp:highGuidance	"Please attend to :Activity02. "
:Action1_Act04	tp:text	""
:Action1_Act04	rdf:type	tp:ActionTutee
:Action1_Act04	tp:responseTo	:Activity04
:Action1_Act04	tp:isCorrect	"TRUE"
:Action1_Act04	tp:alertMessage	""
:Action2_Act01	tp:lowGuidanceMessage	"You skip the physical process and go straight to the final result."
:Action2_Act01	tp:highGuidanceMessage	:Activity02

Figure 1: Augmented concept map **Figure 2: Semantic knowledge base**

Figure 1 provides a visual representation of the graphical organiser we have developed and the associated concept mapping used for tutoring plans. On the left-hand side, a table lists the information related to the clicked node, which is present in red on the right map. For instance, the red node 'CmapPattern01' includes a set of common misconceptions or incorrect links that the tutee might establish, such as 'Water vapour condenses into clouds.' The tutor's role involves assessing the accuracy of these statements and delivering feedback, which is categorised into four types as displayed in the left table: alert message, low guidance message, high guidance message, and correction message.

Furthermore, the map includes nodes for questions, answers, activities, and actions, all of which the tutor may utilise to extent the sequence and logical relationships among the hydrological concepts they intend to teach. Below the map is the basic counts feedback on the quantity of question-answer, activity-action turns and guidance.

After developing the tutoring maps, the SPARQL Protocol and RDF Query Language (SPARQL), which is a semantic query language for databases, can retrieve and manipulate data stored in RDF format (see Figure 2). This integrated interface streamlines the planning and execution of tutoring sessions, making it a useful tool in supporting the tutoring preparation process. Not only do our participants expect to do the tutoring, but they are also preparing for tutoring by anticipating the tutorial dialogical interaction that is typical for peer tutoring. This kind of preparation makes it different from a content-centric type of preparation.

Iterative design: From concept mapping to knowledge mapping

Knowledge maps (KMs) are more abstract than CMs as a data graph referring to an information model, not a visual notation. KMs can be displayed as a (directed, labelled) visual graph like CMs, but this is just one notation for them. In a KM, nodes (concepts) and links (relations) have formally defined meanings that get expressed via the relation between concepts and classes (e.g., “condensation is a physical process”) and via properties of concepts and relations (e.g., “evaporation and precipitation are inverse processes”). They can also take the form of text statements, such as ‘Transpiration produces Evaporation’. KMs are not passive graphical organisers but active information structures that can perform basic reasoning tasks. This moves the pedagogical focus from a representational view of knowledge and understanding to an inferential one (Causton, 2019). We hypothesize that constructing and reasoning with knowledge maps will lead to even stronger learning effects than constructing concept maps and using them as a graphical organiser. And since KMs in our case will include content and pedagogical knowledge (e.g., questions for the tutee and when to raise them) they should make for a powerful learning tool.

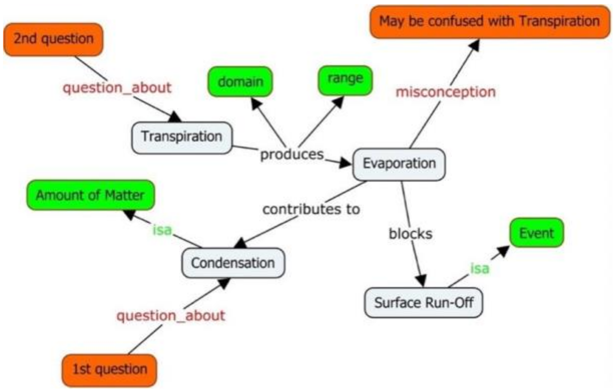


Figure 3: Augmented knowledge mapping

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298 lines (186 sloc)  |  10.4 KB

@prefix : <http://www.semanticweb.org/peter/ontologies/2023/4/tplan/> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix xml: <http://www.w3.org/XML/1998/namespace> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@base <http://www.semanticweb.org/peter/ontologies/2023/4/tplan> .

<http://www.semanticweb.org/peter/ontologies/2023/4/tplan> rdf:type owl:Ontology ;
                                                            <http://purl.org/dc/eleme
                                                            rdfs:comment "An ontology

#################################################################
#    Annotation properties
#################################################################

###  http://purl.org/dc/elements/1.1/creator
<http://purl.org/dc/elements/1.1/creator> rdf:type owl:AnnotationProperty .


#################################################################
#    Object Properties
#################################################################

###  http://www.semanticweb.org/peter/ontologies/2023/4/tplan/alertMessage
:alertMessage rdf:type owl:ObjectProperty ;
              rdfs:subPropertyOf :guidanceMessage .


###  http://www.semanticweb.org/peter/ontologies/2023/4/tplan/answersQuestion
:answersQuestion rdf:type owl:ObjectProperty ;
                 rdfs:subPropertyOf :responseTo ;
                 rdf:type owl:InverseFunctionalProperty .


###  http://www.semanticweb.org/peter/ontologies/2023/4/tplan/correctionMessage
:correctionMessage rdf:type owl:ObjectProperty ;
                   rdfs:subPropertyOf :guidanceMessage .
```

Figure 4: Ontology for tutoring map

In our context, KMs have an additional feature: They do not only contain data (information about specifics) but also about what the data mean (information about concepts, relations, and properties). KMs gain this capacity by including an ontology. An ontology in information science is a kind of data model. Augmented KMs with tutoring planning information can be achieved in the same form as for CMs: by adding sequencing information etc.. The green links and nodes in Figure 3 correspond to ontological information.

To enable student tutors to engage in knowledge mapping, the teacher/researcher needs to prepare a suitable ontology and provide an application that allows the students to express the relations between concepts from the kit to concepts from the ontology. Next step, we will design the ontology in the Protégé and save in GitHub repository (see Figure 4) and restore the tutoring triples in the AllegroGraph knowledge base as shown in the last section. We can provide feedback which goes beyond the one available from CMs in several ways. For instance, in a KM, properties (relations) have a domain and a range defined, specifying which kind of entities a property can be applied to and what values it can take, respectively.

Conclusion

CMs and KMs are not only tools for learning and communication but also provide direct information on the learner’s knowledge activation and integration. Hence, they are an important diagnostic tool and a data type of pivotal importance. To empirically explore if knowledge mapping leads to learning over and beyond concept mapping, next we will conduct experimental studies based on the learning-by-preparing-for-tutoring paradigm and we will compare three forms of preparing for tutoring: (i) unstructured way, (ii) concept mapping, and (iii) knowledge mapping.

In addition to being beneficial to the peer tutors, we see the significance of this study on knowledge mapping in two contributions. The most important contribution is the connection we make between concept mapping and semantic technologies such as knowledge maps. In theoretical terms, this amounts to a repositioning of the pedagogical perspective from maps as graphical representations to maps as external tools for reasoning. It brings concept mapping in closer relation to computational thinking. In practical terms, it allows for a much more scalable and much more flexible use of concept/causal/argument maps -- graphical organisers in general. In infrastructural terms, it allows the distribution of tutoring knowledge across the internet and paves the way for collective knowledge building. The second contribution lies in the integration of content learning with learning about pedagogy for tutoring. While peer tutors are sometimes advised on what to tutor and how to tutor, we are the first to suggest an integrated artefact -- the pedagogically augmented knowledge map -- to that effect. This has the potential to make pedagogical knowledge more accessible and usable for everybody who wants to support peer learning.

Acknowledgement

I am immensely grateful for Professor Peter Reimann's supervision and programming support throughout this Ph.D. project at the University of Sydney.

References

Ali, M., & Falakh, F. M. (2020). Semantic Web ontology for vocational education self-evaluation system. *In 2020 Third International Conference on Vocational Education and Electrical Engineering (ICVEE)* (pp. 1-6). IEEE. https://doi.org/10.1109/ICVEE50212.2020.9243278

Causton, E. (2019). Bringing inferentialism to science education. *Science & Education*, 28(1-2), 25-43. https://doi.org/10.1007/s11191-019-00027-3

Engelmann, T., & Hesse, F. W. (2010). How digital concept maps about the collaborators' knowledge and information influence computer-supported collaborative problem-solving. *International Journal of Computer-Supported Collaborative Learning*, 5(3), 299–319. https://doi.org/10.1007/s11412-010-9089-1

Fiorella, L., & Mayer, R. E. (2013). The relative benefits of learning by teaching and teaching expectancy. *Contemporary Educational Psychology*. https://doi.org/10.1016/j.cedpsych.2013.06.001

Fiorella, L., & Mayer, R. E. (2016). Eight ways to promote generative learning. *Educational Psychology Review*, 28, 717-741. https://doi.org/10.1007/s10648-015-9348-9

Jeevamol, J., & Renumol, V. G. (2021). An ontology-based hybrid e-learning content recommender system for alleviating the cold-start problem. *Education and Information Technologies*, 26(4), 4993–5022. https://doi.org/10.1007/s10639-021-10508-0

Leo, J., Kurdi, G., Matentzoglu, N., Parsia, B., Sattler, U., Forge, S., … Dowling, W. (2019). Ontology-Based Generation of Medical, Multi-term MCQs. *International Journal of Artificial Intelligence in Education*, 29(2), 145–188. https://doi.org/10.1007/s40593-018-00172-w

McLuckie, J., & Topping, K. J. (2004). Transferable skills for online peer learning. *Assessment and Evaluation in Higher Education*, 29(5), 563–584. https://doi.org/10.1080/02602930410001689144

Morita, J., Ohmoto, Y., & Hayashi, Y. (2021). *Integrating knowledge in collaborative concept mapping: cases in an online class setting*. Springer International Publishing. https://doi.org/10.1007/978-3-030-80421-3_12

Roscoe, R. D., & Chi, M. T. H. (2007). Understanding tutor learning: Knowledge-building and knowledge-telling in peer tutors' explanations and questions. *Review of Educational Research*, 77(4), 534–574. https://doi.org/10.3102/0034654307309920

Sadita, L., Hirashima, T., Hayashi, Y., Wunnasri, W., Pailai, J., Junus, K., & Santoso, H. B. (2020). Collaborative concept mapping with reciprocal kit-build: practical use in a linear algebra course. *Research and Practice in Technology Enhanced Learning*, 15(1). https://doi.org/10.1186/s41039-020-00136-6

Tzoumpa, D., & Mitropoulos, S. (2020). Semantic Web Technologies for Ontologies Description: Case study in Geometry Education. *SEEDA-CECNSM 2020 - 5th South-East Europe Design Automation, Computer Engineering*, 0–4. https://doi.org/10.1109/SEEDA-CECNSM49515.2020.9221781

Wu, L., Liu, Q., Zhou, W., Mao, G., Huang, J., & Huang, H. (2020). A semantic web-based recommendation framework of educational resources in E-learning. *Technology, Knowledge and Learning*, *25*, 811-833. https://doi.org/10.1007/s10758-018-9395-7

Cui, Y. (2023). Supporting peer tutoring with graphical organisers and knowledge maps. In T. Cochrane, V. Narayan, C. Brown, K. MacCallum, E. Bone, C. Deneen, R. Vanderburg, & B. Hurren (Eds.), *People, partnerships and pedagogies*. Proceedings ASCILITE 2023. Christchurch (pp. 362–376). https://doi.org/10.14742/apubs.2023.555