ENHANCING CONCEPTUAL THINKING WITH INTERACTIVE CONCEPT DISCOVERY (INCOD)

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Abstract

Interactive Concept Discovery (InCoD), based on Concept Parsing Algorithms (CPA), is a novel learning tool in the context of pedagogy for conceptual thinking. It supports semantic searches of Key Word In Context (KWIC), an interactive procedure that uses text analysis (concordance; collocation; co-occurrence; word frequency) and allows students to explore the course Knowledge Repository (KR) for discovery of conceptual contents. InCoD guides sequential teaching/learning episodes in an academic course by focusing learners’ attention on conceptual meaning.

InCoD is part of a pedagogical approach that is very different from the usual classroom scenario where students are given a problem-solving exercise and asked to solve it individually. Pedagogy for conceptual thinking includes weekly formative assessments, structured to provide opportunities for students to discuss and exchange ideas; to share and contrast points-of-view; to prompt and refresh each other’s memory regarding important details of the conceptual situation; and to ‘compare notes’ about possible responses.

In weekly searches with InCoD the learner reads and annotates found documents, and evaluates their degree of relevance to the specific conceptual situation under consideration; creates his/her Individual Index with alphabetic list of content words and annotations; and constructs concept maps with graphical visualizations that reveal patterns of associations among concepts. InCoD semantic searches prompt class discussions and lead to discovery of relations among co-occurring, subordinate concepts. They provide feedback that identify ‘soft conceptual spots’ in students’ current understanding of important conceptual issues, and guide the instructor to initiate class activities to remedy conceptual misunderstandings. Systematic video recordings of small group discussions in weekly formative quizzes reveal enhanced students’ engagement and peer cooperation, and members of a group listening intently to an individual presenting a convincing point-of-view. Pedagogy of conceptual thinking and peer cooperation in the classroom motivate and engage students, enhance learning outcomes and higher-order thinking. This is particularly important in large undergraduate classes.

Our experience in implementing Interactive Concept Discovery (InCoD) in Canada, Russia, Israel, Australia, and Italy, include: Ontario Institute for Studies in Education of University of Toronto (OISE/UT); Roots and Routes Summer Institute, University of Toronto, Scarborough; Faculty of Engineering and Architectural Science at Ryerson University, Toronto; Independent Learning Center (ILC) of TVOntario; Material and Manufacturing Ontario (MMO) Centre of Excellence; Mount Sinai Hospital, Toronto; Russian Academy of Sciences – Lycee, Ioffe Physico-Technical Institute, St. Petersburg; Meir Medical Center, Kfar Saba, Israel; Faculty of Engineering, Ben Gurion University, Israel; School of Education, University of New England, Australia; and M@label, the Italian national mathematics educational program, coordinated academically by the Department of Mathematics at University of Turin. These implementations include workshops for training of instructors, and classroom implementations in several knowledge domains: Language (ESL; learning disabilities); Social Science (psychology; teacher education); History; Architecture; Mathematics (algebra; geometry; statistics); Science (physics; biology); Health; Business (project management; risk management).

1 INTRODUCTION

The emergent discipline of concept science is a novel generic methodology for parsing and analyzing concepts, applicable to the various knowledge domains and professions, with tools for recognizing, representing, organizing, exploring, communicating, and manipulating knowledge encoded in controlled vocabularies of sublanguages. Concept science documents the evolution of content and structure of concepts and categorization, knowledge representation and use. Certain words, used to
describe regularities in human experience, acquire specific meanings that differ from their meanings in the general use of language. These code words are unique names of concepts - patterns in the data, invariants. The use of code words is common practice in all disciplines and in all domains of knowledge. It originates from the common need to eliminate – at least reduce – ambiguity, and to define conceptual content in precise terms that allow clear demarcation between the known and the unknown.

Code words in scholarly discourse are **lexical labels of concepts in a controlled vocabulary** that encode conceptual content within the body of knowledge in a discipline, a profession, a domain. A lexical label acts as proper name of a regularity, an organizing principle behind a collection of facts in context. Lexical label is often one or more common words (mostly nouns and noun phrases) used to label a recognized pattern in human experience and to communicate a well-defined meaning. Lexical labels of concepts differ from the use of these same words in ordinary language in two important ways:

- Lexical labels of concepts do not encode the literal meanings associated with their constituent words in the common use of the language. Each such label encodes a connoted meaning, rooted in the regularity being considered, that differs from the literal meaning of the word(s).
- Lexical labels of concepts cannot be replaced by synonyms. Each label functions as a proper name of the signified concept.

Initiates – insiders who share the code - know that a lexical label of a concept serves a similar function to that of a proper name, in contrast to ‘outsiders’ who encounter a lexical label and do not associate it with discipline-specific meaning. They assume that the label is just a word in general language, and therefore may be substituted by a synonym: ‘In general language it is easy to find synonymous expressions, but in specialist discourse the exact term for the conceptual equivalent is expected’ [1].

## 2 METHODOLOGY

Conceptual curation is a recent development in curation of large repositories containing digital full-text documents [2]. It includes the use of semantic searches that reveal structured, multi-layered building blocks of concepts with lateral and hierarchical interactions. Concepts are labeled patterns in the data that encode ‘meaning’ in different domains of knowledge: semantic content embedded in them by the situation being documented, and the specific constraints associated with data generated during this evolutionary process.

Content of an academic course is encoded in its main concepts, accessible through a comprehensive collection of full-text digital documents. Such a collection is a **Knowledge Repository (KR)** that may contain all types of relevant digital documents: primary sources; monographs; technical reports; databases (numerical data; images; 3D artifacts; (see: http://research.library.gsu.edu/zotero ). KR opens pedagogical horizons to instructors and learners, and shifts the emphasis from memorization of facts to experiential learning with Interactive Concept Discovery (InCoD), that allows exploration of particular conceptual situations from different points of view, in a particular knowledge domain, represented in different ways by a variety of authors of different documents in KR.

InCoD is a novel semantic search tool based on Concept Parsing Algorithms (CPA; [3]; see also: http://libguides.usc.edu/textmining/tools ; https://voyant-tools.org/). InCoD is a novel learning tool in the context of pedagogy for conceptual thinking ([4]; [5]. It support semantic searches of Key Word In Context (KWIC), an interactive procedure that use text analysis (concordance; collocation; co-occurrence; word frequency) and allows students to explore the course Knowledge Repository (KR) for discovery of conceptual contents. InCoD guides sequential teaching/learning episodes in an academic course by focusing learners’ attention on conceptual meaning.

InCoD is part of a pedagogical approach that is very different from the usual classroom scenario where students are given a problem-solving exercise and asked to solve it individually. Pedagogy for conceptual thinking include weekly formative assessments, structured to provide opportunities for students to discuss and exchange ideas; to share and contrast points-of-view; to prompt and refresh each other’s memory regarding important details of the conceptual situation; and to ‘compare notes’ about possible responses. It is an intuitive, interactive procedure that allows the discovery of elements of the building blocks underlying the lexical label of a concept within a particular context, namely, co-occurring sub-ordinate concepts and relations. This procedure guides the user to construct concept maps that clearly identify internal conceptual structure, namely, hierarchical and lateral relations.
among concepts and their building blocks. A user develops an evolving Individual Index by identifying the lexical label of a particular concept within a context in a discipline; then conducts Key Word In Context (KWIC) semantic searches of this lexical label; evaluates the consistency of appearance of candidate co-occurring concepts and candidate relations among concepts across different documents in KR that contain this lexical label. In successive iterations, the learner:

- read and annotate found documents, then tag and link them to other relevant documents
- mark and save ‘candidate’ lexical labels in his/her Individual Index
- evaluate the degree of relevance of a particular document to the conceptual situation under consideration, and identifies different representations that share equivalence-of-meaning
- construct concept maps - alternative graphical representations of links between concepts and their building blocks

3 RESULTS

Sequential stages of development of Individual Index and concept maps become a dynamically updated and comprehensive record of individual learners Interactive Concept Discovery (InCoD) that document the process and outcomes of sequential research and learning episodes. It reveals the learner’s consistency of ‘drilling down’ for discovering deeper building blocks of the particular concept, and shows the temporal evolution of outcomes of the research-and-learning sequence: deeper levels of comprehension of conceptual content. This digital record may also be saved in a learner’s e-Portfolio as an authentic, evidence-based demonstration of mastery of knowledge [6].

Figure 1 is an example for text analysis of this paper with Voyant Tools (https://voyant-tools.org/). The table at the lower right shows Key Word In Context (KWIC) – CORCORDANCE – of TERM = ‘incod’, namely, all individual locations in this paper where the word ‘incod’ appears, including several context words on the left side and several context words on the right side of the word ‘incod’. In addition, other visualizations and statistics are available (see relevant documents on the website). Figure 2 shows Voyant Tools analysis of TERM = ‘conceptual’ in this paper.
Weekly use of such text analysis tools allows learners to deepen their understanding of specific conceptual contexts in class discussions and weekly formative assessments in the course.

In addition to evolving Individual Indexes, shared between individual students and the course instructor, CONCEPEDIA (Cooperative Conceptual Encyclopedia) is a weekly aggregation of all Individual Indexes of learners in the class, in the context of the course knowledge domain, available to all students in the course. It also include learners’ commentaries on other learners’ annotations, enhance individuals’ reputations as cooperators who contribute to the public good, and reflects the cumulative process-learning-curve of the class.

4 CONCLUSIONS

Our experience in implementing Interactive Concept Discovery (InCoD) in Canada, Russia, Israel, Australia, and Italy, include: Ontario Institute for Studies in Education of University of Toronto (OISE/UT); Roots and Routes Summer Institute, University of Toronto, Scarborough; Faculty of Engineering and Architectural Science at Ryerson University, Toronto; Independent Learning Center (ILC) of TVOntario; Material and Manufacturing Ontario (MMO) Centre of Excellence; Mount Sinai Hospital, Toronto; Russian Academy of Sciences – Lycee, Ioffe Physico-Technical Institute, St. Petersburg; Meir Medical Center, Kfar Saba, Israel; Faculty of Engineering, Ben Gurion University, Israel; School of Education, University of New England, Australia; and M@Label, the Italian national mathematics educational program, coordinated academically by the Department of Mathematics at University of Turin. These implementations include workshops for training of instructors, and classroom implementations in several knowledge domains: Language (ESL; learning disabilities); Social Science (psychology; teacher education); History; Architecture; Mathematics (algebra; geometry; statistics); Science (physics; biology); Health; Business (project management; risk management).

A recent OECD Review of ‘Evaluation and Assessment in Education: Synergies for Better Learning’ [7] provides strong evidence for the important role of formative assessment in enhancing students’ learning outcomes, and notes that ‘The quality of formative assessment rests, in part, on strategies teachers use to elicit evidence of student learning related to goals, with the appropriate level of detail to shape subsequent instruction’ [8]. Our research shows that students’ learning records, including: InCoD-promoted Individual Indexes and CONCEPEDIAS in different courses and knowledge domains, as well as formative assessment outcomes, provide authentic evidence of mastery of knowledge and higher-level thinking (see also: [9]).
REFERENCES


