Countering Selectivity and Enhancing Integrative Complexity through Visualizing Knowledge Bottlenecks

Emergent Research Forum (ERF) Papers

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Abstract

In this study, we propose a redesign of learning activities and assessment tools with the intent to counter selectivity and to enhance integrative complexity in student learning of bottleneck concepts in IT-courses. Bottlenecks constitute concepts that are comparatively complex and thus are more likely to be subject to selectivity by students. Selectivity in all forms – exposure, attention, perceptions, retention, and recall – is thought to diminish the quality of learning processes and outcomes by limiting the extent to which individuals recognize and integrate different dimensions of a given topic. To alleviate selectivity and to enable the integration of concepts covered in the course, we propose the use of concept maps (CM). Concept maps provide a graphical representation of concepts and the associations between them; the associations are labeled to represent discipline-specific propositions. In the proposed study, concept maps will be part of in-class activities, lab exercises, and exams, to be administered in six course sections of three different IT courses. The impact of the interventions will be assessed based on a comprehensive reflective manuscript to be submitted at the end of the semester and that will include concepts from both CM-based interventions and traditional parts of the course. Details of the research model, field experiment design, and an outline of activities are included in this proposal. We believe that concept maps can further integrative complexity, which is a critical 'gluing' mechanism for creating meaningful learning experiences within and beyond a given course. More broadly, the application of integrative complexity can contribute to information processing and decision making which are essential for life-long independent learning.

Keywords

Concept maps, selectivity, integrative complexity, bottlenecks

Introduction

In this study, we use concept maps as a mechanism to alleviate selectivity and improve integrative complexity in a classroom setting (Pace 2017; Shopkow *et al.* 2013; Thoemmes & Conway 2007). Concept maps are visual models of concepts within a given domain that have been shown to facilitate meaningful learning (Novak & Musonda 1991). Concepts refer to the building blocks of a given knowledge domain, while the relationships between the concepts are labeled to illustrate regularities and patterns that exist in the domain (Figure 1). The literature on learning suggests that concepts can enable discovery learning processes in which learners identify and describe logical propositions within a domain autonomously (Novak & Cañas, 2008). Bottleneck areas are particularly difficult for novice learners to comprehend; they require extensive practice and guidance (decoding), as well as unraveling by the experts (Pace 2017). In a course, bottlenecks are areas in which a significant number of students are unable to perform essential learning activities, or succeed in using assessment tools.

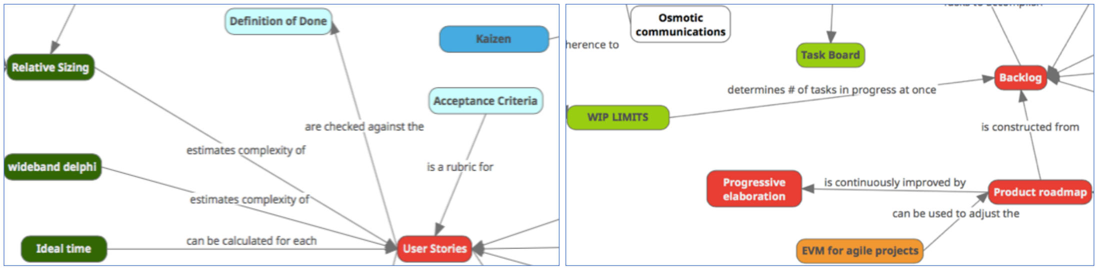

Figure 1: software-generated concept map created by students in a 200-level IT course

Selectivity represents tendencies of exposing oneself to, attending to, processing, retaining, and recalling only a subset of available information (McCroskey & Richmond 2006). Selectivity can impair student learning at many levels. In particular, selectivity limits integrative complexity, which is an individual's tendency to perceive and process different dimensions of a given topic (Suedfeld *et al.* 1992). As a specific form of cognitive complexity (i.e., how complexly people think about a given topic or issue) (Conway & Gornick 2011), integrative complexity consists of the two phases of differentiation and integration. Differentiation involves the perception of different aspects of a subject, and integration is the recognition of connections between those aspects (Suedfeld *et al.* 1992). Prior literature on integrative complexity (Gruenfeld & Hollings-head 1993) has conjectured on the correlation between integrative complexity and task performance. For instance, the performance of conceptual tasks and intellective tasks has been shown to correlate positively with integrative complexity (Desanctis & Gallupe 1987). This study's premise is that enhancing integrative complexity in a course will lead to improvements in the performance of tasks within the scope of the course.

Prior literature has distinguished between state and trait integrative complexity. Trait complexity is less likely to change while state complexity is prone to environmental mediators (Harvey *et al.* 1961; Streufert & Swezey, 1986; Suedfeld *et al.* 1992). Further, research studies on integrative complexity suggest that people across the spectrum on many scales (e.g., religious or irreligious; left wing or right wing) can benefit from practices that would help them enhance cognitive complexity and counter selectivity (Conway *et al.* 2017; Houck *et al.* 2018; McCullough & Conway 2017). To enhance integrative complexity, this research study proposes the use of CM-based learning activities and assessments. To measure integrative complexity, an automated tool (Conway *et al.* 2014; Houck *et al.* 2014) will be used which has been built upon a well-validated 1-7 measurement scale for integrative complexity (Baker-Brown *et al.* 1992). The automated tool examines two dimensions of integrative complexity: dialectical and elaborative, which indicate the extent to which converging (dialectical) or diverging (elaborative) dimensions of a given topic have been integrated (Conway *et al.* 2014). The literature on concept maps[1] suggests an impact on the development of cognitive models and the creation of meaningful learning experiences (Wei & Yue 2017). Concept maps can help to discern patterns and to create connections among segmented topics introduced throughout the semester. This study's proposed model is depicted in Figure 2.

As part of the planned interventions, students will be primed with a list of categories and will be asked to identify concepts from each category and to illustrate the connections among the concepts with logical qualifiers (labels) that are consistent with the body of knowledge in the course and discipline. We believe that priming students with categories may alleviate selective exposure because students are required to consider all categories during their reflection process. As a result, we propose that dialectical integrity may be improved. In addition, we believe that identifying links and their qualifiers, as well the formative assessment provided by instructors, will alleviate selective perception, and thus may enhance elaborative integrative complexity that students establish among concepts introduced in the course. We also propose that these impacts will be stronger for bottlenecks.

H1: Use of concept map learning activities and assessment tools is associated with higher levels of dialectical and elaborative integrative complexity that students establish among concepts within a course.

[1] *https://cmap.ihmc.us/*

H2: Topic difficulty level moderates the relationship between CM-based learning activities and assessment tools and integrative complexity (dialectical & elaborative) in that the positive association is stronger for bottleneck areas.

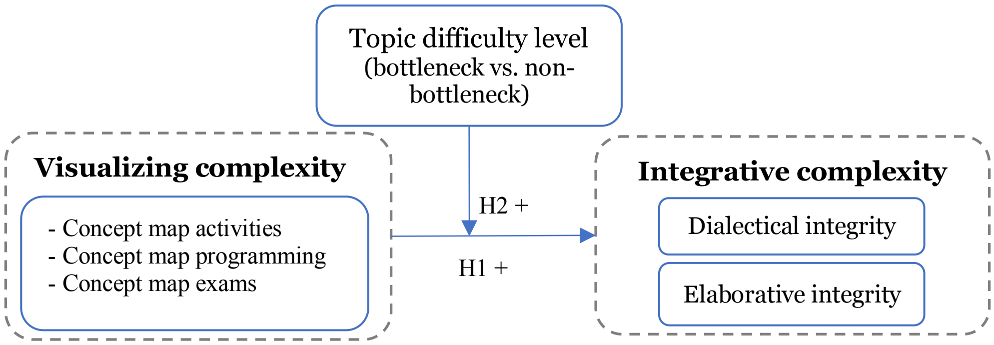

Figure 2: Research model

Methodology

This study's plan is to examine the impact of visualizing concepts and their relationships with concept maps on students' integrative complexity of bottleneck areas in the course. We plan to conduct within-subject field experiments with a 2×2 design (concept map vs. no concept map, bottleneck vs. non-bottleneck topics) in six sections of three different IT courses across two institutions; each course experiment will focus on four different areas: two bottlenecks and two non-bottleneck topics; one pair consisting of a bottleneck and a non-bottleneck topic will be part of control and another pair will be part of intervention. At the end of the semester, students will be asked to compose a reflection on all four areas. The analysis will then compare the levels of dialectical and elaborative integration for the areas covered during the intervention, and also assess the differences between bottleneck and non-bottleneck areas. The no-intervention period will include written (or electronic) reflections and regular exam questions. The intervention period will include Paper & pencil (or programmed) concept maps and concept-map based exam questions. A written reflection assignment at the end of the which covers all four areas will be used to assess dependent variables.

Bottlenecks

We plan to select eight major areas of each course, four areas to be considered bottlenecks and four non-bottlenecks. The lists will then be refined based on input from a panel of faculty members in the respective departments and in the larger IS community through the Association of Information Systems Special Interest Group on Education. We expect that including bottlenecks in the experimentation will lead to more holistic knowledge maps at the end of the course. Eventually, the experiment will include two non-bottleneck (NB1, NB2) and two bottlenecks (B1, B2) areas. In both regular and concept-map activities, students will be given categories of topics to reflect on and summarize.

After identifying bottleneck areas, students complete traditional written reflections on a pair of non-bottleneck and bottleneck areas and another pair of reflections using concept-maps. The regular activities will contribute to a comprehensive reflection document prepared in-lab and electronically. The purpose of using in-lab exercises is to provide access to rich media through which students may choose to express their ideas. The concept-map activities will culminate in a coding exercise in which students will write a Python program to combine and visualize the two concept maps. The rationale for using coding instead of visualization software is that coding preceded by paper and pencil activities is thought to offer a level of engagement that further enriches counter-selectivity experiences.

Example of concept-map learning activities

During interventions, students will be asked to reflect, discuss, code, and take tests with a focus on concepts and their connections. Depending on the settings, groups can be primed with a list of concepts, categories, or none. Examples of the instructions for paper and pencil CM-activities and exam questions are included in Figure 3.

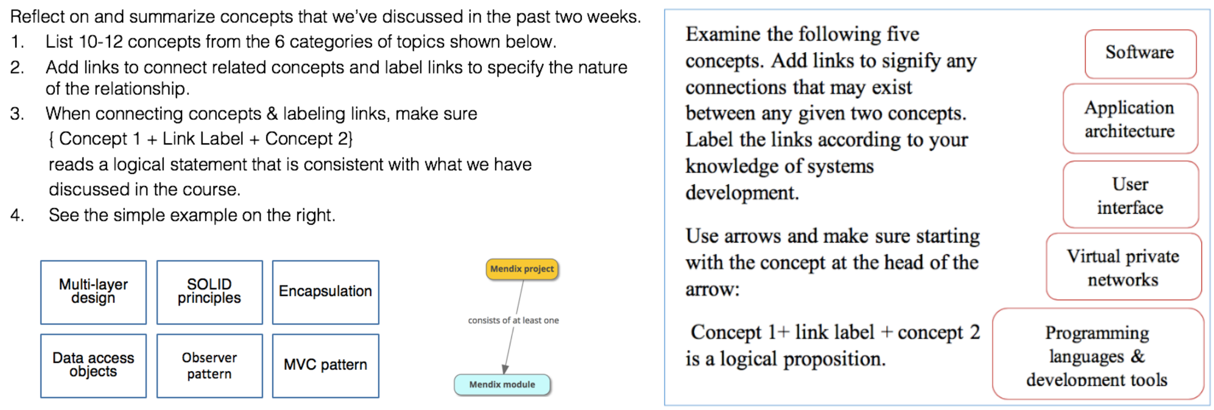

Figure 3: Paper and pencil concept map (left), concept-map question (right)

Formative assessment on the activities and CM-based exam questions

Both interventions and control discussions will involve formative assessments by instructions. Prior research studies on discussions (Javadi *et al.* 2019) and concept maps (Wei & Yue 2017) will be used as a guide to establish a standardized formative assessment structure across the six course sections; possible feedback on concepts, relationships, qualifiers, and other areas may look like (1) *Missing key concepts; inclusion of non-relevant concept*, (2) Missing key relationships; inclusion of non-logical relationships, (3) *Incorrect label; inaccurate label; wrong direction for the relationship* , and (4) New concepts (from other IT courses, experiences, or other disciplines)Examples from work, other courses, other disciplines, or real-life. For the interventions, a subset of traditional multiple-choice questions will be converted to variations of CM-based questions. One example is described in Figure 3. A pool of 60 questions will be created for each course. The list will be condensed to 30-40 questions after pilot-testing with students who have taken the course in the past. The use of CM-based questions requires a change in grading rubrics and points assigned to each question; for instance, a 1-point multiple-choice question may correspond to a 4-point CM-based questions. Because changes such these are extensive, we have decided to conduct only within-subject experimentations.

Dependent variable

Dialectical and elaborative integrative complexity will be measured using the automated integrative complexity measurement tool by researchers at Political Cognition Lab at the University of Montana (Houck *et al.* 2014). Students will write a 2-page course reflection document, which will include all the areas covered in the four activities. This 2-page reflection-on-the-course will be used to measure how many concepts from each of the four areas are included and how well the concepts are integrated. The analyses will examine the possible impact of CM-based interventions, and the role that topic difficulty level may have played.

Insights from Pilot Experiments & Conclusion

To prepare for testing the proposed model, several activities that are described in this manuscript have been performed in two sections of a 200-level undergraduate Information Systems (IS) course and one section of a graduate IS course. The pilot activities, however, did not distinguish between bottleneck and non-bottleneck areas. All three priming methods (with categories (Figure 4, left), with concepts , or none) have been examined. The quality of the maps created by students in the pilot tests indicate a need for priming, either with categories or with concepts. Another option is to allow for an incubation phase, followed by group brainstorming and a class-level discussion, in order to identify key categories or concepts. This three-phased approach is consistent with recommendation of research studies on brainstorming because a phased approach ameliorates concerns about production blocking and/or anchoring bias (Pinsonnault *et al.* 1999); a possible drawback of a phased approach is the lengthened duration of activities. Pilot test activities with no priming, concepts, and categories have been completed in 15 to 20 minutes at the end of a 75-minute class session. In both the undergraduate and graduate classes, the group engagement was higher during the concept-map coding activities. Students were told to combine two concept maps that they had created using paper and pencil, and to refine the maps based on formative feedback they had received from the instructor. Pilot tests observations are consistent with the premise of this study that selectivity is a persistent phenomenon and the integration of topics requires specialized assignments and attention, particularly in courses where all-inclusive projects are non-existent.

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