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Application of Cytoscape to the Analysis of Diagrams of Mechanisms Underlying Patient Problems

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In problem based learning (PBL) tutorials in a medical context, students solve authentic patient problems with the educational aim to develop their reasoning capacity. A key activity to facilitate development of their reasoning capacity in a tutorial is the construction of diagrams of mechanisms that explain patient problems. These diagrams are networks of discrete elements (such as headache) of patient problems. Analysis of these diagrams may yield insights into students' reasoning styles. To achieve this aim, we employed an application called Cytoscape, which is capable of visualising and analysing networks, to study these diagrams. In this preliminary study, we showed that Cytoscape can be used to analyze these diagrams of mechanisms produced in PBL tutorials. We found that students tend to reason in a hierarchical manner. Parameters are also defined that can be used to identify incorrect and missing links in their reasoning processes.

Key words: Problem based learning, Diagram of Mechanisms, Cytoscape, Medicine, Reasoning and Higher Education

Introduction

The explosion of medical information fuelled by the Internet and the digital revolution is challenging the field of medical education. Medical students and medical practitioners face the challenge of being able to critically appraise, assimilate and apply valid and relevant knowledge to solve patient problems. Problem based learning (PBL) is an important educational approach and philosophy aimed at developing these capacities.

A core educational objective of PBL is to empower students with the skills of basic clinical reasoning, cooperative learning and integration of knowledge of various perspectives of patient problems (Barrows & Tamblyn, 1980; Norman & Schmidt, 1992). In PBL sessions, students construct diagrams of mechanisms to holistically reflect the causes of and pathophysiological processes underlying patient clinical signs and symptoms, incorporating relevant psychosocial issues (Guerrero, 2001) and knowledge from different disciplines, such as anatomy, physiology and pathology. Developing these diagrams is a challenging task as this requires competent critical reasoning skills (Croskerry, 2009). The student-constructed diagrams, especially during initial weeks of entering medical schools, are most likely simple, incomplete and even incorrect in certain situations. Analysis of these diagrams should provide insights into the processes of clinical reasoning and how they can be captured in the diagrams, and may also yield information for guiding students to develop reasoning skills through constructing these diagrams.

The diagrams of mechanisms consist of discrete elements, such as pathophysiological processes (e.g. dehydration) and symptoms (e.g. headache), linked as a network (Figure 1). Analysis of these diagrams using software for visualizing networks could help in extracting useful information that might be otherwise hidden in the diagrams. Cytoscape is an open-source network visualization and analysis software (Smoot, Ono, Ruscheinski, Wang, & Ideker, 2011) and is well maintained by educational and industry organizations including Agilent Technologies. Our own experience with this software in a biomedical domain is very positive (Wang, 2011).

In this preliminary study, our aim was to uncover students' reasoning styles by analyzing various attributes of these diagrams of mechanisms with the aid of the Cytoscape.

Summary of work

PBL is implemented in a metropolitan Australia Medical School for both Year 1 and 2 student groups, with 24 groups in total. Each group is composed of 10 - 12 students and they work through one case each week. Each case usually starts off with patient symptoms, followed with history, clinical examination and completed with patient management. Student groups are encouraged to construct diagrams of mechanisms by drawing on a white board, facilitated by tutors. These diagrams were then photographed for analysis using Cytoscape 2.8 (Figure 1). Thus far fifteen of such diagrams have been analyzed and more will be examined as we gather more of these diagrams. Analysis of these diagrams demonstrated that they are similar in terms of the capture of main pathophysiological processes and different in terms of the organization of these processes. Ethics approval for this study was obtained from the UWS Human Research Ethics Committee (approval ID H9989).

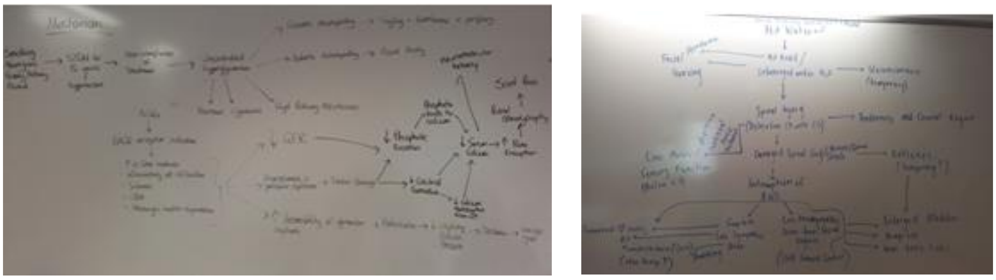

Figure 1: Photographs of original images of diagrams of mechanisms generated by PBL groups for two different PBL cases.

We hypothesize that these diagrams contain information on the patterns of reasoning processes. These patterns are reflected by groups' understanding of problems from various perspectives including psychosocial, biological and pathological perspectives, and at body organizational levels including molecular, cellular, tissue/organ and body systems. While a subjective and holistic appraisal of these diagrams may yield some insights, using Cytoscape enables us to extract and analyze information embedded in these original images in a systematic and efficient manner.

Analysis of the overall patterns of the diagrams of mechanisms

Using Cytoscape, we explored the overall patterns of these diagrams as shown in Figure 2. To fully understand these patterns an explanation of the network is outlined here. Each circle (or node) in the network represents an element which can be a pathophysiological process/concept, patient's symptom, sign or investigation finding. The arrow (or edge) between these circles generally means "leads to" or "results in". The arrangement of these nodes provides clues for reasoning patterns exhibited by students. In this particular PBL case, we found that the overall arrangement of these processes and concepts is a simple structure with the causal processes displayed at the top, and symptoms and signs towards the bottom (Figure 2). This arrangement may represent the cause-effect and progressive nature of patient disease processes, thus supporting the hierarchical organizational mode of knowledge (Novak, 2010) in a patient problem context. The result from this preliminary study suggests that more patterns may be revealed in a subsequent, expanded study of these diagrams.

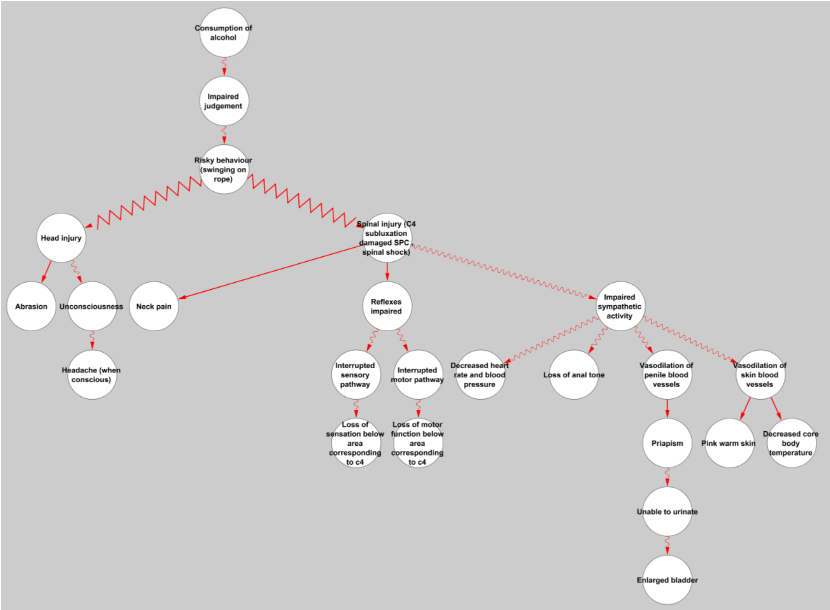

Figure 2: The overall pattern of an example of a diagram of a mechanism visualised using Cytoscape 2.8.

Analysis of particular attributes of diagrams of mechanisms

In addition to the overall patterns, Cytoscape enables us to visualize patient symptoms, organizational levels at which particular processes operate, and organizational level transition steps between causal processes and resultant processes (Figure 3). Analysis of these elements could provide clues to students' reasoning capacities or styles in the context of real patient problems. In Figure 3, the patient symptoms are highlighted as hexagons. It is clear that most of symptoms are terminal nodes, i.e. no child nodes attached to them. This finding suggests that students' reasoning was aimed at explaining patient symptoms. The organizational levels at which particular processes operate are indicated by the sizes of the nodes, the largest ones signify the psychosocial levels such as the "Consumption of alcohol" (single black arrow**).** The smallest circles represent organizational level of tissue/organs such as "Enlarged bladder (double black arrows) while middle sized circles indicate body/system level such as "Impaired sympathetic activity" (single white arrow). This example demonstrates that the students are able to clearly combine psychosocial issues with pathophysiological processes at a system and organ/ tissue level. However, no cellular and molecular processes were considered in this case. This may be the reflection of the nature of this particular patient problem, the high level reasoning processes displayed by the students, lack of knowledge at these levels or combination of these.

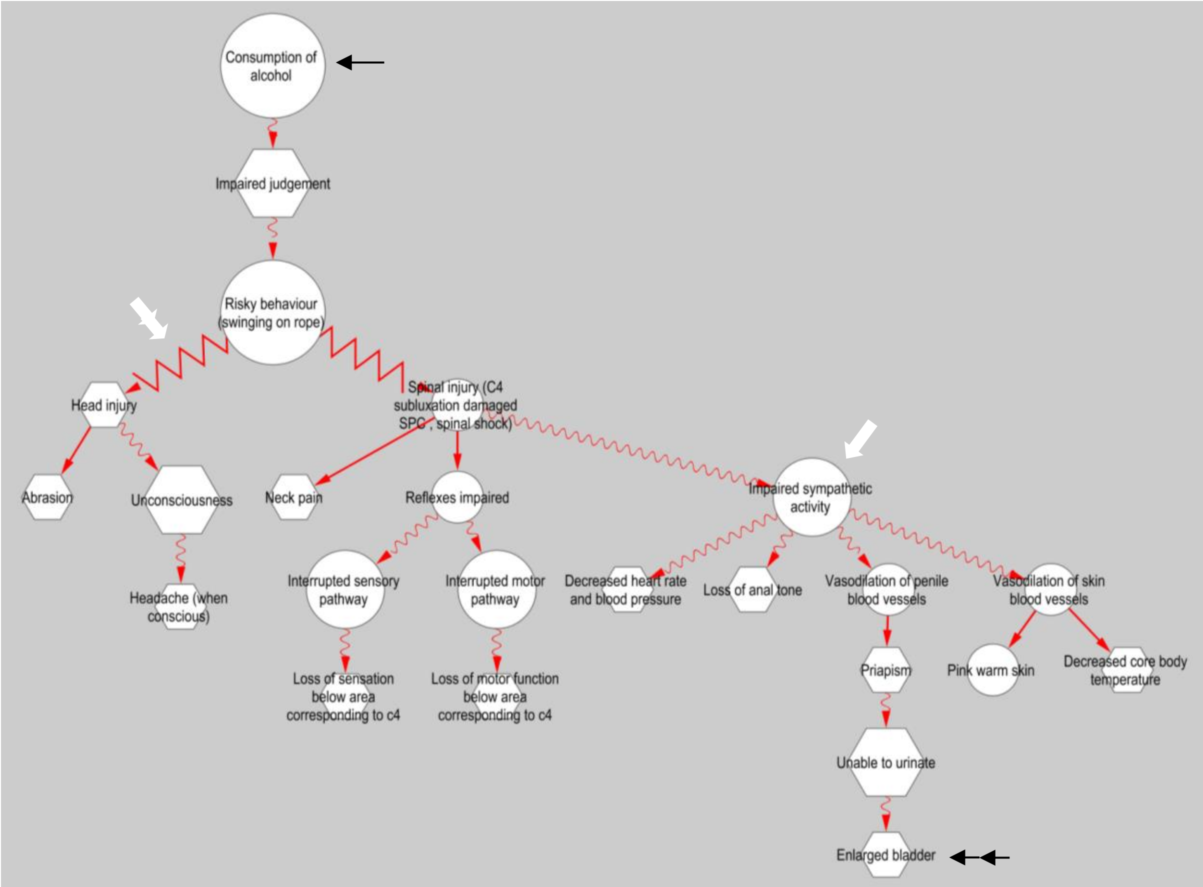

Figure 3: The visualization of the patient symptoms (hexagon), organisational levels (size of the circles) at which particular processes operate, and organisational level transition steps (edge styles) between causal processes and resultant processes using Cytoscape 2.8

In addition to the process and concept (nodes), the linkages between them (edges) can also be used to represent information visually. The zigzag lines (double white arrows) demonstrate that an organization level is skipped from one process to another. For example, from “Risk taking behavior (swinging on rope) - which is at a psychosocial level to the “Head injury” – which is at an organ level, the body/system level was skipped. Adding a middle process of “patient hitting on physical object(s)”, now it reads as “Risk taking behaviours (swinging on rope) → “Patient hitting to physical object(s)” → “Head injury”. The reasoning process is now more complete and logical. This analysis suggests that skipping one or more organization levels as highlighted in the graph can be a useful way to pinpoint possible inappropriate and missing links in students’ reasoning processes. According to Marcum, dual processes occur in the clinical reasoning – a non-analytical and an analytical process integrated with metacognition processes (Marcum, 2012). It is suggested from the analyses that students groups have relied on heavily on the analytical process in the PBL settings, perhaps due to the fact that they lack clinical experiences.

Taking all these results together, it is suggested that two types of integrations occur in PBL mechanisms: i), horizontal integration that combines a psychosocial perspective with a pathophysiological one of patient problems; ii), vertical integration that considers patient problems at all levels of body organization. These findings demonstrate that the PBL educational approach is geared towards the model of biopsychosocial medicine (Novack et al., 2007) and deep learning. The parameters defining these two dimensions of integration are summarized in Table 1. The significance of these parameters is that they can be used for guiding students to construct logical mechanisms, leading to meaningful learning.

Table 1: Parameters useful for analysing the diagrams of mechanisms incorporating psychosocial issues.

Overall pattern	The overall structural patterns of the mechanisms including hierarchical and possibly others.
	Nature of the processes/concept, i.e. causative processes, symptoms, signs and investigation

Particular attributes	findings.
	Body organizational levels represented by the processes/concepts from molecular, cellular to body system levels and psychosocial level.
	Organizational level transition between causal processes and resultant processes.

Conclusion

- This preliminary study shows that Cytoscape can be used to visualize and analyze the diagrams of mechanisms produced in PBL tutorials.
- A hierarchical pattern for organizing different aspects of patent problems is used by students. More patterns may be discovered in a further expanded study. These patterns reflect the thinking styles of PBL groups.
- We defined parameters for looking into these diagrams of mechanisms (Table 1). They can be used for guiding students to develop more meaningful diagrams of mechanisms
- These initial findings warrant future work aimed at further analysis of these diagrams of mechanisms.

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