"Tell me about the process": Exploring Visual Analytics to unveil Collaboration and Concept Mapping Processes

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Abstract. Final products of students' collaborative work do not inform much about individual contributions and whether there are processes leading different groups to either high or low levels of achievement. A great advantage of using learning technologies is that traces of students' collaborative processes can be automatically captured. This paper presents our first steps in extracting and visualising different aspects of the face-to-face collaboration processes to enhance teacher's awareness, in the context of small groups of students building concept maps at an interactive tabletop. We propose an approach, mixing bottom-up and top-down approaches, to inform the design of visualisations that can provide insights to teachers about the collaboration during the task. It is based on a manual empirical analysis of the sub-processes and strategies followed by students whilst only using the electronically observable data.

1 Introduction and Related Work

Teachers commonly conduct small-group activities to promote students learning and collaboration in the classroom. Unless they observed the groups without interruption, teachers are usually not well aware of the collaborative process that they followed [11] and usually assess collaborative work based on the final products. However, these final products do not inform much about individual contributions and the process that lead different groups to either high or low levels of achievement. Moreover, the quality of the final products does not necessarily correlate with the quality of collaboration [13]. A great advantage of using learning technologies is that some traces of students' collaboration can be automatically captured [12]. This is particularly important for face-to-face scenarios (e.g. the classroom), where student conversations are not usually mediated by the learning system.

There has not been much exploration on ways to visualise either the collaborative or the work processes and making them visible to enhance teacher awareness. Dolenh's [3] work created visualisations about *task progress* of small groups working at tabletops in a classroom. The visualisations were shown on a vertical display and were updated in real time. Basheri et al. [1] explored the use of a timeline visualisation showing the main actions of students working at a tabletop interface. However, authors never intended to provide teacher's with distilled information. Our previous

work at a multi-tabletop classroom explored the use of visualisation generated in real-time and shown on a teacher's dashboard [4]. However, these visualisations only outlined information about individual participation and student's artefacts.

This paper presents our first steps towards building an interface that can automatically analyse and visualise aspects of the face-to-face collaboration process. We exploit the affordances of interactive tabletops for capturing the learners' *digital footprints* that are generated while collaborating face-to-face [5]. Tabletops provide an environment where students can decide whether they work in parallel or as a group entity [6]. In this paper, we analyse the particular processes of small groups of students performing problem-solving by building concept maps at a tabletop. Concept mapping is a technique that let students graphically represent their understanding of knowledge space[2]. A concept map is a directed graph where nodes represent concepts and linked between them with propositions, which are labelled with an associated linking word (often verb-based). Usually, there are one or more main concepts that are directly associated to the focus question that the concept map is addressing.

We propose an approach to inform the design of visualisations that can be used to provide teachers with key information about the student's collaboration and concept mapping processes. This paper describes **(i)** the *empirical analysis* that we envisage to use as the basis for constructing a system that can automatically provide a higher level of abstraction to the low level student application log*s* and **(ii)** the *feasibility of our approach* by generating a set of visualisations about group's collaborative processes based on results of this empirical analysis.

2   Context of the Study

A total of 60 university students participated in the study, grouped in triads. The experimentation took place in a controlled environment (see Figure 1, left). Each triad was asked to provide an answer to an initial focus question: *What types of food should we eat to have a balanced diet*? The goal for students was to read a one-page article based on the Australian Dietary Guidelines 2011; build an individual concept map at a personal computer using CmapTools; and then build a group concept map at the tabletop. Each work session lasted 30 minutes for the individual task and around 30 or 35 minutes for the tabletop task. In this paper, we focus on the second task only. This task was subdivided in two stages: brainstorming (where students could only add and move concepts) and linking (where students could additionally create links between concepts) phases. Students were instructed to spend 5 to 10 minutes on the brainstorming stage, and 20 to 25 minutes on the linking work. Students could also have on-screen access to their individual maps created in the individual task to either show to the other team members or just to recall what they did previously on their own.

The multi-touch tabletop was linked to the Collaid sensing system that can automatically collect differentiated touch activity (e.g. who added a concept or created a link) and speech events (who spoke and for how long) for each of the sixty users during the 20 sessions. Additionally, each session of collaborative work was video recorded. Further details about the dataset can be found in [7].

3   Approach

We focus here on higher aspects of collaboration and knowledge building. We manually analysed the video recordings to identify qualitative aspects of collaboration such as social roles, leadership moments when students reach consensus or insights about how they regulate their collaboration process. Our challenge is to bridge different levels of analysis and to underline information that could inform some kind of support tool for the teacher. Our encoding approach is illustrated in Figure 1(right). It shows a pyramidal representation of the levels of abstraction of the data about the collaboration process that can be obtained from the logged and differentiated student activity. Previous analysis of these data provided insights about strategies that differentiate high from low achieving groups [7], trends linked with knowledge acquisition [8] and the opportunity to generate visualisations for teachers automatically [6]. These findings helped us create tools that can automatically enhance teacher's awareness.
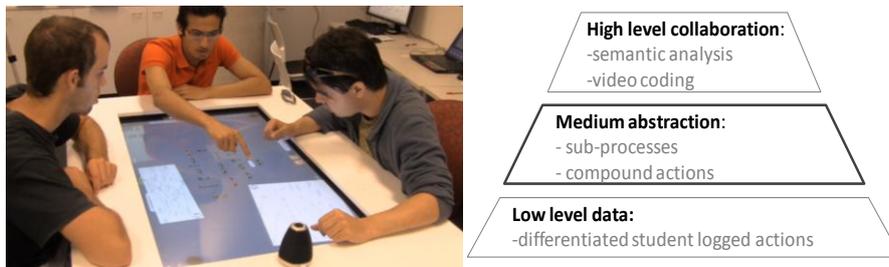
Fig 1. Left: A triad building a group concept map at the tabletop. Right: Pyramidal representation of the levels of abstraction of the student's data that can be captured in our setting.

We now want to go one step further and present information to the teacher that they would manually look for. In this paper we propose a coding scheme based on the qualitative observations conducted by a human but considering only the data that can be automatically collected. The aim is to be able to automatically generate visualisations of the collaborative and concept mapping processes with some level of semantic understanding. In other words, the coding scheme must be linked to the artefact (the concept map being built at the tabletop) and the data collected by the technology.

Based on previous work that identified the sub-processes of individual concept mapping [9, 14]and our previous detailed observations of the process of concept mapping at the tabletop [7]we defined a coding scheme and encoded each of twenty sessions to reveal the succession of sub-processes. We focused on observing the meaning of the low level logged data, therefore, we avoided a deep analysis of oral interactions. We defined 8 events:

1. **Sharing individual map**: when the user opened her map and expressly shared it with others in the group. The map could be enlarged, returned, moved towards others.

2. **Consulting own map**: when the group members consulted their own individuals maps. The consultation occurred when the learner opened and read it for herself even if s/he talks about it. When the map was opened but the user did not pay attention to it for a long time, the map was considered as closed.

3. **Generation of concepts**: when students put concepts on the map. It occurs mainly during the first minutes of the work. They could as well add new concepts in the second step of the task. Few groups used really the brainstorming method proposed by Osborn [10] which focus on quantity, withhold criticism and defer judgment.

4. **Organisation of concepts**: when students focus on just spreading concepts on the whole surface in order to delete redundancies, create groups or subgroups of concepts, emphasise hierarchies, add missing concepts. If students add several new concepts, we consider it is a new phase of "generation of concepts".

5. **Generation of links**: when students focus on creating links choosing for each the direction of the arrow and the linking word. Numerous cognitive conflicts may emerge at that stage. This sub-process may reflect different levels of understandings and misunderstandings as well: e.g. concept of fibre, micro nutrients, fats.

6. **Revising and layout**: when students focus on revision of the map making small changes to the map (some generation of new links or editing linking words). This sub-process usually emerged as an iterative process with "Generation of links". When students rearrange "aesthetically" links, they see often in the same time new problems in the meanings and have to reorganise their ideas.

7. **Adding the main concept(s):** when the group focused on the main concept (in this case: Balance Diet) by placing it at the top or centre of the map.

8. **Speaking**: We noted the speaking time of the group without considering who the speaker was. This gives no information about the quality of oral interactions, but the Collaid logging system automatically logged more detailed speaking information.

4   Visualisations

We illustrate the type of information that can be shown, exploiting the log data interpreted according to our coding scheme, through two visualisations: *stacked bars* and *blocks*. They both show the succession of sub-processes in collaborative concept mapping. The *stacked bars visualisation* presents the process as a Gantt diagram. The *blocks visualisation* is a compacted representation of the first visualisation. Figures 2 and 3 show two well differentiated example groups. Group A is an example of a discontinuous process and Group B is an example of a continuous process.
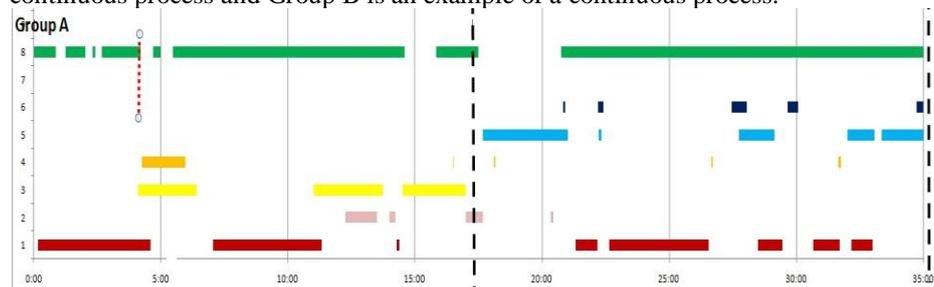

Fig 2. Stacked bars visualisations for group A. The vertical axis represents: 1- Sharing individual map; 2- Consulting own map; 3- Generation of concepts; 4- Organisation of concepts; 5- Generation of links ; 6- Revising; 7- Adding the main concept(s); and 8- Speaking.

Group A started sharing individual maps (dark red bar in Figure 2). At that point we can guess a search for mutual understanding. At minute 4 the group added the main concept (see red dotted line) and started creating concepts (yellow bar). At the same time, students recognised the concepts according to students' understanding of the key question (orange bar). Students shared their maps again at minute 7, and then started again to create concepts again; during that time some learners checked their own map (pink bars). It was not until minute 16 that the group jumped to the linking step (see blue bars afterwards). The group stopped speaking while "generating links". Each linking period is interrupted by a period when students shared perspectives. The group revises their propositions rather rarely (few dark blue bars).
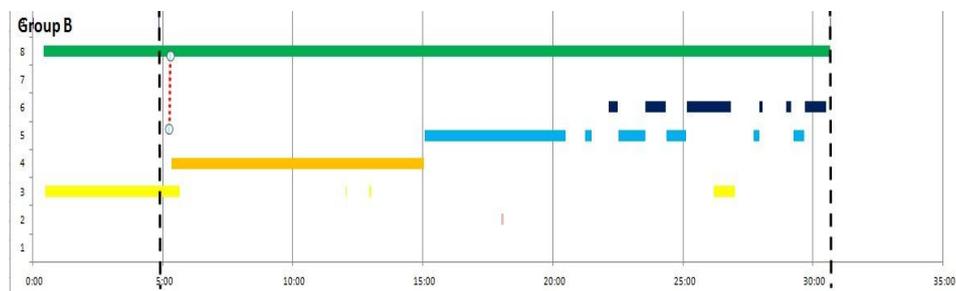

Fig 3. Stacked bars visualisations for group B.

By contrast, Group B presents a very different pattern. The talking is continuous (green bar in Figure 3), and all sub-processes flow without interruption. Students never looked at their individual maps. This does not mean that learners did not look for mutual understanding because the talking may have been dense. Students started creating concepts (yellow bar) and decided to jump to the linking stage at minute 5 (see black dotted line). Afterwards, they focused on the key concept and reorganising concepts (see red dotted line and orange bar). At minute 15 they started generating links (blue bar). Meanwhile, the group revised the links (dark blue bars) and added a few more concepts. The group finished earlier than Group A.
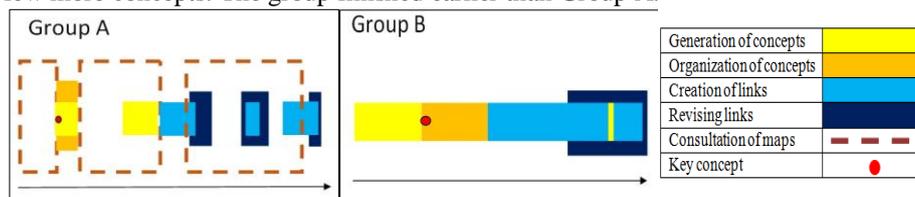

Fig 4. Block visualisations for groups A (left) and B (middle). Reference colour coding (right)

The *block visualisations* summarise the information conveyed in the stacked bar visualisations in a way that can be readable at a glance. Figure 4 shows the visualisations for groups A and B demonstrating that some key differences may be highlighted. In this case, the periods of consulting perspectives are underlined and so the periods of no-action. However, information about the continuous of talking is lost.

5 Conclusion

We presented our first steps towards analysing and visualising different aspects of the face-to-face collaborative concept mapping process. Our approach aims to find the right balance between semantic information that can be associated with students' logs to create a teacher's tool using visual analytics. We are currently working on including key qualitative and quantitative indicators that can be obtained from the concept maps. Further work needs to be done to design a way to automatically associate semantic information to the logs, validate that the automated methods match the human observations and evaluate a full set of visualisations with real teachers. Beyond the description of different sub-processes of concept mapping, our future work also aims to highlight special events or behaviours which may provide clues of low or high collaboration for a teacher.

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