Abstract

Using multimodality in presentations which include speech, visuals, and gestures, influences cognitive processing load and the subsequent understanding of students. However, having them produce (differing) representations of their knowledge that support descriptions, explanations and problem solving, not only aids reasoning and reflection, but gives insights into the development of the conceptualizations which underpin their understanding. An experimental study gives support to these conclusions.

1. Introduction

The acquisition of knowledge usually involves interaction with presented materials and sources, which are structured under a supporting pedagogy that takes account of students’ previous knowledge, the limitations of working memory and the specific characteristics of perceptual, visual and verbal coding. This comprehension process is both constructive and integrative and particularly important for key concepts where an insecure understanding can cause recurrent problems. This paper argues that multimodality is useful in addressing these issues, not only in the design of teachers’ presentations, but in students representing their knowledge in forms that can support elaboration, reasoning, explanation giving and problem solving. A series of experiments has provided data which supports these contentions, and gives some insights into the process of developing conceptualizations that underpin understanding.

2. Related research

In designing multimodal presentations the differing processing capabilities of the visual and verbal coding systems can reduce the cognitive load, and the gesture modality can also act as a semantic integrator, revealing the emotive interest of presenters in the material, and their empathic response to the audience. Specifically, Moreno and Mayer recommend a “modality principle” maintaining that, when visual and verbal materials are combined, delivering verbal material as speech rather than as written text is more likely to prove effective [1]. Also gestures, which are closely associated with speech, are themselves visual and enactive, and semantically coherent within communicative acts [2].

When comprehending presented material, students construct mental representations in association with their previous knowledge. But demonstrating understanding requires reasoning and reflection, and it is useful for students to represent their knowledge in ways that indicate conceptual units and the associations between them. Mind maps, Concept maps, Flowcharts and Schematics are techniques for giving such visual representations. However, it is worthwhile considering which type of mappings are most appropriate for students receiving and using multimodal presentations, and what these representations can show about the nature and process of developing understanding. Our experimental studies have been directed at these objectives.

3. The study design

Four key topics were chosen: Cable Suspension Bridges (resolution of forces) Hot Air Balloons (Archimedes Principle) Waves (Wavelength, Amplitude and Phase) and Geometric Transformations (Matrix Multiplication). For each topic four experienced teachers were asked to prepare five-minute presentations on two of the topics—in four formats—using speech with a chosen visual and gestures as appropriate. The formats were a Board Presentation as in a seminar; a Desk presentation as in an individual tutorial; a Computer Display using telepointing, and, for completeness, a Voice-Over with no gestures. All presentations were recorded for computer display and each student received one (different) presentation format given by one (different) presenter on each topic.

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The study followed a balanced design and 32 student participants viewed 128 presentations in total. After the multimodal presentation there was a (written) recall test, and a repeat of the presentation; then students were asked to draw a labelled diagram and give a written explanatory account. Finally, participants undertook a reasoning task and gave ratings (a ten-point scale) on the clarity of the content of the presentation, the helpfulness of the visual and of the gestures.

4. The analysis

To illustrate the main themes of this paper the analysis will focus on the student data from topics of the Cable Suspension Bridge, and, particularly, the Hot Air Balloon. These data involve 64 protocols given by 16 students. Of these 35 preferred the Board Format, 18 the Desk, 7 the Telepointing and only 4 the Voice-Over. These data seem to show an appreciation of the ‘presence’ factor of the presenters. On the 10-point ratings Clarity of Content had an average score of 7.7, the Visual support 7.4, and the Gesture support 8.0. The Visual support ratings were reduced for the Voice-Over format (though the same visuals were used for all formats of the topic) and the Gesture Support ratings for the Board Format were superior to the Desk and the Telepointer presentations (8.5 to 7.8 and 7.6 respectively).

However the main interest of the study concerns the responses given by students on the Descriptive, Explanatory and Problem solving tasks. For the Descriptions of the Hot Air Balloon and Suspension Bridge topics, all students, across all formats, were able to draw a correct labelled diagram of components. However the Board and Desk groups were superior when it came to labelling the forces (which were not shown on the visual).

The Explanatory written accounts of students were interesting because many showed “conceptual closure”. For example, on the Hot Air Balloon topic, 16 students noted that the burner heated the balloon-air, concluding that hot air rises so the balloon rises. [This suggests convection currents in the balloon lift the balloon.] A further 10 students noted that the hot balloon air becomes less dense causing the balloon to rise. [This suggests the balloon will stop rising when its air density equals that of the atmosphere...not correct] Only 6 students (4 from the Board, and 2 from the Desk groups) gave a complete explanation of the balloon air expanding, so air leaves the balloon and the balloon system loses weight....so the balloon rises. Similar profiles and examples of closure were shown on the accounts of the balloon sinking and on the explanations of how the Cable Suspension Bridge works. The students were satisfied with their explanations probably because of the strong links to their previous knowledge. Hot air does rise, as do less dense fluids and so the conclusion of the presenters (that the balloon will rise) could be short-circuited even though the explanations made no direct links to the principle of buoyancy/weight forces. In problem solving the correct buoyancy/weight principle was given by 25 students but only 2 of them gave an adequate explanation of the height ceilings of larger and smaller balloons. Again this shows the weak linkage between the explanation process and the forces principle.

5. Discussion

These data show a progression in understanding from a secure description of the functional components of the system, to process knowledge of how the system works (but showing conceptual closure), to only a partial understanding of how process relates to buoyancy principles and how they can be used in problem solving. However even partial conceptualisations provide a framework for reasoning and a sequence of short interactive questions was designed (e.g. Why doesn’t the air pressure in the balloon increase?) to enable students to realise the balloon is an Open System, and through the balloon air weight reduction, to make the link to the buoyancy/weight principle. In summary for secure understanding it is useful to have three knowledge representation systems: a visual labelled diagram to support functional descriptions, a state-change explanatory map focusing, in its nodes, on the component that is undergoing the causal and consequent changes (e.g. the balloon air), and a system principle diagram of the buoyancy/weight (forces) that supports problem solving. Such a progression enables students to arrive at summary conceptualizations that helps them manage their understanding.

6. References