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Technoliteracy and learning: An analysis of the quality of knowledge in electronic representations of understanding

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Abstract

Recent educational research from a socio-cognitive perspective has validated students' collaborative engagement with new technologies and heightened understanding of influential factors shaping the effectiveness of peer interactions, learning contexts and computer interfaces for enhancing learning. This paper focuses on an analysis of the complexity of knowledge in student-designed, electronically created texts for what they might reveal about learning with technology. It reports on a study with 17-year-old female students whose collaborative learning process in subject English was mediated by the creation of electronic concept maps and Web files to represent their developing understanding. To analyse these electronic texts, evaluative criteria templates were developed from the Structure of Observed Learning Outcomes (SOLO) taxonomy, integrating levels of understanding with the distinctive characteristics of multimodal text production. Findings indicated not just the incremental acquisition of conceptual understanding equated with cognitive change but that the level of understanding might also be positively influenced by the students' length of exposure to computer-mediated learning practices. As well, the criteria templates have emerged as useful evaluative tools for classroom assessment or further research when analysis of the level of complexity of student-created, electronic artefacts is required.

Keywords: Technoliteracy; Computer-mediated learning; Evaluation tools for e-learning; Collaborative learning process; Electronic representation of learning

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1. Introduction

Many primary and secondary teachers consider computer-based activities as integral to and appropriate for the classroom practices of their students. Internet searches, word-processing and multimedia presentations are being adopted increasingly by humanities teachers. However, the integrated use of computers for assisting thinking processes and as a focus for communicative interaction has been less apparent in teaching practice and research literature, especially with secondary school students. The teacher's ability to design the types of activities that effectively apply collaborative inquiry to electronic learning tasks for deepening student knowledge remains crucial, whatever the subject area, student age or software choices (Jonassen, Peck, & Wilson, 1999; Light & Littleton, 1999; Mercer & Wegerif, 1997; Scrimshaw, 1997; Underwood & Underwood, 1999; Wegerif & Dawes, 1997).

One significant pedagogical approach gaining credence through research and classroom practice is students' collaborative engagement with problem-solving, computer-based tasks for more effective learning. The organisation for such activities requires careful consideration of the mediational role of the computer (Bliss & Säljö, 1999; Underwood & Underwood, 1999; Wells, 2002) as well as the communicative and intellectual dimensions of collaboration (Mercer, 1995). Wells (2002, pp. 200–202) rightfully contends in his notion of the "spiral of knowing" that knowledge is constructed through reflection and mental engagement with people, problems and artefacts. It is this "symbiotic interaction of individuals, tools, artefacts and social practices" that becomes so important for "the development of human thinking, learning and reasoning" (Bliss & Säljö, 1999, p. 10). This socio-cognitive view of education moves beyond a singular, computational use of new technologies and advocates engaged peer interactions with a shared computer activity. It recognises the interdependence of communicative interaction, new technologies, the design of computer-based tasks and focused activity for learners to become critical thinkers and creators of knowledge.

Research with 8–12-year-olds has foregrounded how learning with technology might be enhanced through heightening consciousness of the students' language choices in their collaborative meaning-making. Mercer's (1995) "social modes of thinking framework", for example, advocates the development of students' facility with "exploratory talk" (Mercer, 1995, 2002; Mercer & Wegerif, 1997; Wegerif & Dawes, 1997) wherein group members constantly challenge and counterchallenge the quality of the knowledge they generate (Wegerif & Mercer, 1997). Contextualised as a specific joint task to deepen the level of critical reflection, this dialogical model of reasoning foregrounds the intrinsic role of communicative interchange in meaning-making. With older learners, added impetus to cognitive change can be achieved through focusing that communicative interaction on their design of artefacts (Wells, 2002) with knowledge-creation software tools to represent their understanding.

Bliss and Säljö (1999) argue that as thinking and reasoning are distributed between people and across artefacts and social institutions, students will only be able to create meaningful learning in technology-mediated environments by active construction "through communicative and interpretive processes in concrete human practices" (p. 10). When this view of collaborative knowledge-building focuses on a computer-based, problem-solving activity, whether at a software interface or through student design, deeper understanding of an issue or concept can result (Jonassen, 1992, 1995; Lehrer, Erickson, & Connell, 1994; Reader & Hammond, 1994; Scrimshaw, 1997). Ideas-processing software in particular embodies social constructivist beliefs about active meaning-making as it facilitates an iterative process for constructing and reconstructing knowledge, progressively, repeatedly and with ease, complementing metacognitive processes visually and electronically. So just as exploratory talk can shape "a shared communicative space" (Mercer, 2002, p. 141) for meaning-making, networked computers with Web-authoring and ideas-processing software can be utilised as a virtual, collaborative writing space (Bolter, 1991) or problem-solving space (Jonassen et al., 1999), so becoming an important vehicle for generative learning processes. With such tools, students can represent their knowledge electronically amidst actual or virtual collaborative meaning-making processes.

This article will first introduce the notion of technoliteracy as foundational for a pedagogical model that seems appropriate for prompting the effective integration of collaborative inquiry with new technologies. The concept of design will be posited as a dynamic agent for activating this model with its central construct of "students-as-designers". The third section explores ways of generating meaningful learning with technology used collaboratively for knowledge-creation purposes. Through an analysis of the complexity of knowledge evident in electronic representations of understanding created by teenage student-designers, it will be argued that technoliterate practices can support effective learning and that the specially designed evaluative tools were useful for making discriminating differentiations in those multimodal texts.

2. Technoliteracy: integrating information communication technology with literacy practices

Current approach to classroom integration of technology tends to involve wordprocessing or multimedia presentations, whether as tools for learning or modes of assessment presentation. This model of technology "integration" is anchored to the perceived need of student acquisition of marketable skills for the information age. It does not, however, capitalise on the potential of electronic cognitive tools to enhance the learning process or to facilitate students' more critical engagement with subject content.

Digital Rhetorics (Lankshear et al., 1997), a comprehensive investigation into the relationship between literacy and technology in classroom practice across three Australian states, advocated student mastery of the "operational", "cultural", and "critical" dimensions of both literacy and technology. These three dimensions were seen as requisite for critically thinking about contemporary literacy and technology practices in teaching and learning. Integrated technology use in classrooms should be synonymous with learning *with* technology (Bigum & Green, 1993) so that the focus becomes the cognitive and social dimensions of learning rather than the application of isolated technological skills. To this end, the term "technoliteracy" (Kimber, 1998) articulates the convergence of technology and literacy practices through applying practical processes to curriculum content.

The technoliteracy model (Kimber, Pillay, & Richards, 2002) foregrounds both technical and intellectual skills as integral to learning and communication with new technologies. In this model the operational and cultural dimensions are defined as the basis for knowledge acquisition, whether through functional literacy practices, basic technological operations, or the location and identification of relevant information. With the design dimension, students are encouraged to construct electronic representations of their knowledge as a way of deepening and communicating their understandings, the critical dimension, and purposefully developing their technology skills. Thus the technoliteracy model targets the integration of technology skills, computer-based cognitive tools and literacy practices to increase the learners' thinking in the critical dimension. Design, then, becomes the shaping metaphor for both knowledge construction and the balanced integration of the four dimensions in that model.

3. Design as an agency for engaging students in knowledge construction

The concept of design connotes creativity, critical reflection, and the vision for melding relationships and patterns in composition by assembling ideas, images or information into a coherent creation. Design has been posited as the key factor in adding intellectual value to content or concept in the Information Age (Mitchell, 2000). Strong evidence also suggests that the application of design principles both fosters and supports communicative practices and learning processes.

The New London Group (2000) argues that the element of design "restores human agency and cultural dynamism to the process of meaning-making" (p. 36). Here learners engage in active transformations of patterns of meaning across different media and genres. When combined with collaborative learning, the application of design principles to classroom activities offers a powerful direction for generating developmental learning. If the computer activity involves collaborative interaction, then the social dimension in the construction of knowledge is activated. In a digital classroom, therefore, the notion of design becomes both the goal for creating reflective representations of knowledge and the process for linking the operational, cultural and critical dimensions to develop deeper levels of learning.

With educational technology, the notion of design becomes particularly pertinent for deepening learning. Mayes (1992, 1993) recognised that program designers of a hypermedia system learned more than the students using it, and posited that students as authors of programs should have a better learning experience than students as users of such programs. Open-ended software like ideas-processing programs have great potential for students to become active creators of knowledge (Scrimshaw, 1997). This metaphor of design positions students to develop a conception of themselves as authors of knowledge, not just consumers of knowledge. The constructs of "students-as-designers" of representations of knowledge and "teachers-as-designers" of constructivist, computer-mediated learning experiences for their students therefore encapsulate learning *with* technology.

4. Knowledge construction: learning with technology

In problem-solving environments mediated by computers, learning outcomes have been found to be more productive when pairs talk constructively, mutually sharing and debating knowledge (Underwood & Underwood, 1999). Other views of meaningful learning with technology similarly rest on a constructivist platform with "active, constructive, collaborative, intentional, conversational, contextualised and reflective learning" (Jonassen, 1995, p. 62). This model of learning is predicated on the students' active construction of knowledge, not passive reception. It resonates with Scrimshaw's (1997) emphasis on the "learner as knowledge creator" (p. 104) and the use of open-ended software by different groupings of students who have the opportunity to choose the level of complexity of content that they include and the manner in which they represent it. It is reflected in the construct of student-designers of electronic representations of knowledge. One important factor affecting the success of such collaborative, technology-based enterprises is the choice and design of the task itself (Underwood & Underwood, 1999).

One accepted method for aiding the active construction of meaning is concept mapping wherein new information is assimilated with "old" via identified propositional relationships (Ausubel, 1968). This meta-learning strategy involves the externalisation of thoughts into spatial representations of knowledge that reputedly prompt deeper reflection and associative thinking (Boulton-Lewis & Dart, 1994; Jonassen, 1992; Mayes, 1993; Reader & Hammond, 1994). Concepts are represented in nodes and unidirectional, bidirectional or cross-linking arrows represent a propositional relationship between nodes. In reflecting on the visual representations of knowledge structures, learners can move surface facts into patterns of conceptual organisation. Through accentuating the relationships between ideas, whether cause and effects or gaps in knowledge, the learner becomes more discriminating, integrating these distinctions in content into a more coherent knowledge structure. Considered debate about what information to include, exclude or combine can become a powerful impetus to cognitive change in an effective group (Underwood & Underwood, 1999).

Yet it is not the extent of information alone that reflects the depth of understanding, but its categorisation and relational pattern. In fact, it is essential to revise concept maps for more sophisticated or consolidated schemas to emerge (Reader & Hammond, 1994). The construction of concept maps can be a tedious task by hand, but user-friendly, concept-mapping software can economise on time and effort in reorganising nodes and repositioning links, allowing more latitude for the refinement of thinking required for more coherent understanding. Thus cognitive growth can be facilitated by the use of both the concept mapping process and the technological tool.

Traditionally, concept maps are associated with interlinked nodes on horizontal surfaces. When the limitless dimensions of cyberspace are considered, Web files could be considered as virtual versions of concept maps, aligned hypertextually rather than spatially on a single plane, but still in clear relationship to each other. Separate Web screens or nodes of multimodal information are purposely linked by the creator to other nodes, whether within the parent file or to the World Wide Web, to relate, amplify, illustrate or juxtapose aspects of nodal content. Student-generated concept maps and multimodal presentations can be embedded in a Web screen, adding dynamic dimensions to the electronic text. When the whole file is considered as an entirety, even though linked hypertextually to a wider virtual network, it can indicate the level of knowledge generated and represented by its creator/s. Thus the creation of the file represents both the process of knowledge construction and the developing record of the creators' collective understanding. However, such multilevel concept maps while providing rich picture of the concepts can be difficult to manage and navigate. Thus it must be used cautiously.

Table 1
Descriptors for levels of Structure of Observed Learning Outcomes (SOLO) taxonomy

SOLO taxonomy	Descriptors	Adaptations of descriptors
Terms developed by Biggs and Collis (1982) from Ausubel (1968)	*Descriptors of SOLO taxonomy levels developed by* Biggs and Collis (1982)	*Adaptations of Biggs and Collis' Descriptors of SOLO taxonomy by* Boulton-Lewis and Dart (1994)
Prestructural	A state of incompetence, where nothing is known	No evidence of any knowledge of the processes of learning
Unistructural	Where one relevant aspect is known	One relevant aspect of learning is understood and focused on
Multistructural	Where several independent aspects are known	Several independent aspects of learning are presented. These are not integrated into an overall structure
Relational	Where aspects of knowledge are integrated into a structure	Relevant aspects of learning are integrated into an overall structure
Extended abstract	Where knowledge is generalised to a new domain	The integrated knowledge of learning is generalised to a new domain.

The difference between discrete facts/ideas and a coherent knowledge structure reflects the learner's success with assimilating information and forging propositional relationships (Ausubel, 1968). An examination of the structural organisation of ideas in student-created texts, frequencies of higher order thinking (as distinct from lower order thinking) and relational thinking can help reveal the level of learning achieved by the creator. The Structure of Observed Learning Outcomes (SOLO) taxonomy (Biggs & Collis, 1982), developed from Ausubel's (1968) theory of meaningful learning, has been used in the evaluation of concept maps, primarily as it discriminates between levels of understanding in verbal texts. Its five levels range from lower order *unistructural* and *prestructural*, to higher order *multistructural*, *relational*, and *extended abstract* (see Table 1, column one). Biggs and Collis's (1982) descriptors for these levels of structural organisation (column two) were adapted by Boulton-Lewis and Dart (1994) in their hybridised version of the SOLO taxonomy used in analysing concept maps and verbal data (column three).

The SOLO taxonomy provides a means for evaluating the complexity of thinking in data from humanities subjects. As higher levels of knowledge are synonymous with connectivity, it is the type of linking that can indicate the depth of relational understanding (Reed, Ayersman, & Liu, 1996), whether in nodal content or the links between them. Most research with concept mapping has been in scientific domains, valuing hierarchies and causal linking (Novak & Gowin, 1986; Pillay, 1999; Rye & Rubba, 1998; Starr & Krajcik, 1990). Lehrer et al. (1994) semantic categorisation of links in Hypercard stacks as structural (continuation of an idea or characteristic), explanatory (causes, leads to) or elaborative (alternative representation of, personal comment) mirrors the conceptual differences in thinking articulated in the SOLO taxonomy and seems appropriate for evaluating humanities content.

Given recommendations for the combination of collaborative inquiry with integrated technology use for assisting students in their meaning-making as outlined above, research into technoliterate practices in humanities classrooms seemed an appropriate undertaking.

5. The study

Against the above backdrop a case study approach was adopted to explore the nature and complexity of knowledge developed by senior secondary school students adopting technoliterate practices as student-designers in humanities subjects. The knowledge represented in the student-created electronic artefacts was evaluated qualitatively and then quantified by methods developed from Biggs and Collis (1982), Boulton-Lewis and Dart (1994), Novak and Gowin (1986), and Lehrer et al. (1994). The development of the students' knowledge was also mapped against the length of their exposure to technoliterate practices.

5.1. Sample

Three senior humanities classes from a metropolitan private secondary school for girls (16 and 17-years of age) participated in the larger study from which the data reported herein is drawn. This article details the analyses of the electronic knowledge representations generated by two classes of subject English, both taught by the same teacher but for different periods of time. The *English x1* class (22 students) joined their teacher in their final year, consequently experiencing only six teaching months of technoliterate practices by the time of the study (six months). The *English x2* class (19 students), taught by the same teacher in their computer-mediated environment for two years, and had longer exposure to technoliterate practices (14 months).

5.2. The electronic learning environment

The computer-mediated classroom used in the study was resourced with six networked computers, a fixed liquid crystal display (LCD) projector, and a data projection screen. Software used by the students included Microsoft Word, Front Page and PowerPoint (Microsoft® Corporation, 1997) and Inspiration (Inspiration®, 1997). Forty of the participants had home access to the school's intranet.

5.3. The task

The school's Senior English work program specified four weeks' study of contemporary drama as the final curriculum unit for the 17-year-old students, to be assessed orally by the class teacher at the end of the unit. In non-technology classrooms, all students in the one class studied the same play. The study participants could choose one of four play titles before being directed to work collaboratively yet autonomously to create their own group Web file and a series of individual concept maps to represent their knowledge. Group discussion, the critical analysis of print and electronic texts, and oral presentations in preparation for the end-of-unit assessment were also specified. Group membership was determined by the students' selection of play title.

The process of the construction of electronic concept maps and Web file required individual students to prepare three maps during their collaborative work period. Weekly completion of maps was recommended but students could choose the timing and topic for their maps. Concept maps and PowerPoint presentations could be embedded in the group Web file as part of the group's collective knowledge on the topic and as a visual component for their final oral assessment. Collectively, the range of electronic texts also represented the scope of the group's adoption of and proficiency with technoliterate practices.

The total number of student-generated electronic artefacts included 70 concept maps from individual students and 9 group Web files containing 88 separate screens and 33 embedded concept maps (some being duplicates of the individual creations) and 11 PowerPoints. The analyses of these artefacts afforded a close view of the processes of learning and not just the final learning outcome for the unit.

5.4. Data analysis tools and methods

The aim in evaluating all student-generated artefacts was to ascertain (a) the level of knowledge they represented, (b) the quality of the design and (c) the level of technology skills evident in their construction. Suitable scoring rubrics were required to reflect the nature of these electronic texts and these evaluation goals. Jonassen et al. (1999) argued that effective rubrics should include all of the important elements of the unit of focus, unidimensionally, to ensure that each factor is addressed separately, but showing ratings as distinct, comprehensive and descriptive. By these means, the rubric can provide "rich information about the multiple aspects of the performance" which should be more useful than a "contrived summary score" (p. 224). Thus the scoring rubrics devised for this study set descriptions of specific features of the electronic texts against levels of proficiency based on the hybridised variation of the SOLO taxonomy (Biggs & Collis, 1982) developed by Boulton-Lewis and Dart (1994).

Web screens, concept maps and PowerPoints share similar characteristics, logics and grammars, although specific qualities of each impacted on the design of the evaluative tools. All include nodes of thought and links, whether unidirectional or cross-linked, associative or sequential, static or dynamic. Yet the subtleties of difference needed to be reflected in scoring rubrics suited to each type of electronic artefact, allowing for clear categorisation and scales of difference (Jonassen et al., 1999). Thus the SOLO levels, *nodal content* and *aesthetic appeal* remained the same in each set of scoring rubrics but details for the structure and classification of links differed (see Appendix A for evaluative criteria for Web files and B for concept maps).

In Web files, the nature of links was defined as *internal* (within own Web file creation) or *external* (to the World Wide Web). The function of internal Web links was determined by the type of association made between the onscreen hotlink word and the subsequent screen: (a) basic *structural* (showing the continuation of an idea, or a whole-part characteristic); or (b) *explanatory* (as in causal); or (c) *elaborative* (where an alternative representation or personal comment was cited), after Lehrer et al. (1994) (Appendix A). In concept maps, the nature of the link was either *uni*- or *bi-directional* or *cross-linked*. The function of the link was determined as for Web screen linking (*structural*, *explanatory*, *relational* or *elaborative*) with attention to the naming of the propositional relationship between nodes and the addition of *cross-links* (Appendix B).

As Web screens have a greater potential for presenting *factual and interpretive detail* than smaller concept map nodes, they required a full identification of the types of information presented on each Web screen as defined in the second criterion for content (Appendix A). Concept maps can include *levels of hierarchies*, *categorising concepts* and *colour or symbol differentiation* to indicate the sophistication of structuring of the mental schema, so this was acknowledged in the inclusion of three separate criteria in the design of the scoring rubrics (Appendix B). A three-point differentiation was incorporated in each descriptor and SOLO criterion band by the addition of a plus or minus as most of the artefacts were expected to fall within the multistructural level (Biggs & Collis, 1982; Boulton-Lewis & Dart, 1994).

In accord with the dual scoring method developed by Boulton-Lewis and Dart (1994) and adopted by Pillay (1999), three separate data analysis tools were designed to ensure a fine-grained evaluation of the level of knowledge and quality of design in each concept map/Web file. They were designed in response to the strengths and inadequacies perceived in previous research studies evaluating the level of knowledge revealed in concept maps. The criteria templates (Appendices A and B) were adapted primarily from the SOLO taxonomy (Biggs & Collis, 1982), scoring rubrics for evaluating concept maps (Boulton-Lewis & Dart, 1994; Novak & Gowin, 1986), and the link evaluation method (Lehrer et al., 1994). They were used for qualitative evaluation, identification and frequency counting, each adding another layer of understanding in the analyses. The frequency counts of the instances of qualitative differentiation between basic and more complex knowledge generated rich data for analysis, and facilitated a range of meaningful comparisons in the discussion of results.

5.5. Procedure for coding and evaluating Web files

The screen content of the Web files was initially analysed qualitatively using the Web file criteria (see Appendix A) that specifically focused on content (*nodes and factual and interpretive detail)*, organisation (the *nature of internal linking* and *external*), and design (*aesthetic appeal*) to give an overall *SOLO rating*.

Each item of text represented on a Web screen or embedded PowerPoint screen or concept map was identified qualitatively and coded as *fact* (historical or textual), *example* of a point or idea (or quotation), *label* (as in name of a character or a heading, for example, "setting"), *concept* (for example, "prejudice"), *relational thinking* (for example, "Edward has power over Helen") or *extended abstract thinking* (where multiple viewpoints were expressed). The nature and function of the linking was determined as previously explained. The aesthetic appeal of the artefact was inferred by its quality of design and artistic impact. This required the addition of another criterion (*balance*, *proportion and colour combination* in its design). Categories included low (L), moderate (M), high (H) and very high (VH) aesthetic appeal. The overall screen node was then classified as *structural*, *conceptual*, *relational* or *extended abstract*, after the SOLO taxonomy.

Two sets of frequency counts were tabulated: one solely for Web screens, including content and elements of design; and one for concept maps embedded in Web screens. This procedure allowed detailed analysis of the nodal content, linking, design elements, SOLO level and technology skill level. All details from the Web file analyses were summarised before the means of all SOLO levels, design and technology skill ratings were determined for the Web file. While the means were in effect reductionist of masses of descriptive details, they were derived from three different sources and they did allow a comparative overview. An equivalency table was prepared to convert all alphabetic ratings to numerals. All numerical equivalents for SOLO level, design and technology skills ratings were then tallied and averaged to produce a mean for each element for every group of students from the two English classes.

5.6. Procedure for coding and evaluating concept maps

Many researchers using concept maps as indicators of levels of knowledge acquisition, developed variations on the evaluative tool originally devised by Novak and Gowin (1986) from Ausubel's (1968) learning theories. Numerical scores are allocated to identified hierarchies of knowledge, progressive differentiation of concepts, and integrative reconciliation of concepts (Novak & Gowin, 1986). Variations to those scoring rubrics for concept maps were adapted by a number of researchers in structured scientific domains (Boulton-Lewis & Dart, 1994; Pillay, 1999; Rye & Rubba, 1998; Starr & Krajcik, 1990). More relational patterns of understanding than rigid scientific hierarchies were anticipated in the humanities students' artefacts, reflecting the nature of the subject content. Three templates were designed to meet these purposes.

The first template outlined characteristics of concept maps in terms of the SOLO level, nodal content and quality of design similar to that designed for the Web screens. Criteria for levels or hierarchies and categorising concepts matched those distinctive features of the structural organisation of concept maps. Because ideas-processing software easily allows changes to shapes and colours of nodes and links to suggest semantic or symbolic linkage between concepts, the evaluative template added *colour or symbol differentiation* to the SOLO taxonomy elements for organisation.

The second template recorded identification of the specific types of information apparent in the concept map's nodal type and content, similar to that of Web screens. The types or purposes of links were identified and tallied. A third template tabulated all these interpretations as frequency counts and provided an overview of the differences in scores attributed to each of the three maps.

Fig. 1 provides an example of the identification and coding attributed to one node from each of the three concept maps prepared by Caitlin (*English x2*). The type of node is identified to the top left of the node as *conceptual* (C) or *extended abstract* (EA). Other coding for the nodal content includes *fact* (F), *example* (eg), *label* (L) and *interpretative detail* (I). To ensure readability in reproduction, Caitlin's choice of a dark green colour of the first two nodes has been lightened.

There are minimal differences in nodal content, shape or colour in the first two nodes. Both record one *example* (eg), a quotation from the play, two *labels* (l) in the names of characters, one instance of *interpretation* in attributing "strongly" to a character's actions, and both use the basic *concept* of "themes" to define the node. The major difference is the addition of the conceptual rela-

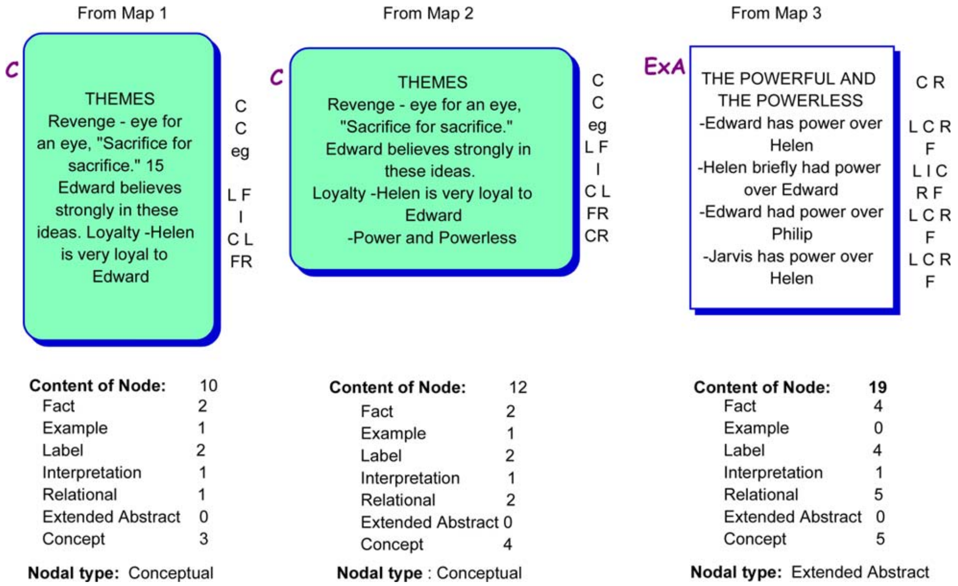


Fig. 1. Comparative view of a student-created node from each of three concept maps prepared in the learning process. Nodal type and nodal content have been identified and tallied.

tionship (''power and powerless'') which helps elevate the score from 10 to 12. The significance of this concept is realised in the third node defining the relationships of power between characters. As well, the higher number of relational associations made under this superordinate concept has elevated the nodal content to 19 and the type of node from conceptual to extended abstract as multiple perspectives on the topic are offered. The incremental increase in the rate of instances of higher order thinking can be discerned by combining the tallies of relational and extended abstract thinking, that is, from 1 (Map 1) to 2 (Map 2) to 5 (Map 3).

Caitlin's structural organisation also changed. In her first map, the Theme node was discretely placed in the bottom right hand corner of a map of four layers of nodes in four different colours with minimal unidirectional linking. In her second map, the Theme node had been elevated to the second bottom row of five layers, using the same colours, but again distinctly isolated. In her third map, the Theme node was centrally positioned in a balanced and related cognitive structure containing six layers of nodes (Appendix C). This map illustrating Caitlin's gradual refinement and consolidation of ideas could have resulted from her group's collaborative deliberations as much as the software. Her group's endorsement of her cognitive structure was reflected in its selection for embedding in their Web file.

6. Results

This summary of results collates the analyses of all individual electronic concept maps and group-constructed Web files from both *English x1* and *English x2* classes. Frequencies are presented for the three main elements of concept maps and Web files, *types of nodes*, *nodal content* and *links*. A distinction is made between basic and the higher order types of thinking associated with more complex understanding. For example, basic levels of information or conceptual understanding are identified as *conceptual* or *structural* (nodes), *fact*, *example*, *label*, *concept* or *interpretation* (nodal content), and *structural* linking. Descriptors like *relational/relational thinking/explanatory* and *extended abstract/elaborative* indicate more complex knowledge reflected in the levels of synthesis and comparison. The evaluation of all data sources allowed for comparative evaluations in terms of time-related exposure to technoliterate practices.

6.1. The analysis of electronic representations of understanding

Table 2 presents all details of the attributes of knowledge identified in the electronic creations, and allows a comparative appreciation of differences between the two classes. It compares the progressive and cumulative nature of knowledge generated by both classes. Means are used for all attributes of knowledge recorded for the key components in the individually constructed electronic concept maps because different numbers of maps were presented from each class. However, raw frequencies are used for details of the group Web files as all individuals in each class contributed to their group's Web files, and thus the totals for the whole class.

Column 1 distinguishes between *English x1* and *English x2*, between the three electronic concept maps (all individually created) and the class Web files (all group created). Columns 2–15 present the means for all attributes of knowledge under the three key components of *nodal type*, *nodal content* and *links* calculated using the methods and templates discussed previously (see Appendices A and B). The total units of knowledge generated for each concept map or Web file are presented in column sixteen. The SOLO levels and design ratings recorded in the last two columns were determined for the artefact by the three-step process previously outlined. These ratings represent the mean derived from all levels attributed to each Web screen, PowerPoint and concept map embedded in the Web file.

Rows five and eight for each set of class results present the totals for all attributes in each key component for the individual electronic concept maps and group Web files respectively. Rows four and seven, however, present the totals for units of complex knowledge identified in each of the key components. The final row presents the grand total of all units of knowledge aligned with the higher order SOLO ratings and design levels for both electronic concept maps and Web files for the whole class.

An examination of the total units of knowledge in the *Total* column provides some understanding of both the quantity and quality of learning generated by the students in their electronic representations of knowledge. Both classes steadily increased the numbers of units of knowledge from map one to map three and then to the Web file which cumulatively manifests the knowledge generated by the whole class; however, *English x2* had the highest scores at every stage of concept map development. While there was a difference of 7.4 in the means for the total units of knowledge generated in the first map by the two classes (61.1 for *English x1* and 68.5 for *English x2*), the gap had increased to 31.2 (85.9 for *English x1* and 117.1 for *English x2*) by map three. The grand total indicates that *English x2* (2450) generated twice as many units of knowledge as *English x1* (1164.3).

Table 2
Frequencies of attributes of knowledge generated by the Year 12 English cohort.

Mean for class members' individual electronic concept maps and total raw frequencies for group web files
With differentiation according to length of exposure to integrated technology use

KNOWLEDGE REPRESENT-ATIONS	NODAL TYPE				NODAL CONTENT							LINKS			TOTAL[1]	SOLO	DESIGN
	Conceptual	Structural	Relational	Extended Abstract	Fact	Example	Label	Concept	Interpretation	Relational thinking	Extended Abstract	Structural	Explanatory	Elaborative		SOLO	Design Rating
English x 1 n=22																	
Concept Maps																	
Map 1	2.3	11.3	0.3	0.1	8.5	0.4	9.1	3.8	11.5	0.9	0	11.4	1.3	0.2	61.1	2xR-	3xH+ 6xH
Map 2	3.6	13	2.3	6.1	10.5	3.5	9.3	4.1	13.1	3.1	0	14.6	1.7	0.4	85.3	1xR 3xR-	1xH- 6H+ 9xH
Map 3	4.5	10.5	4.6	0.4	17	4.1	7.1	6.5	12.9	4.1	0	12	1.1	1.1	85.9	5xR-	5xH+ 7xH-
Complex Knowledge			13.8							8.1			5.8		27.7	11xR	37xH
Total		59						129.5					43.8		**232.3**		
Class Web Files	17	8	11	0	265	92	141	81	114	97	4	102	0	0			
Complex Knowledge			11							101			0		112	1xR	1xH
Total		36						794					102		**932**		
															1164.3	**12xR**	**38xH**
English x 2 n=19																	
Concept Maps																	
Map 1	1.7	9.5	2.8	0.2	16.4	2.3	11.1	2.1	6.9	0.8	0.1	12.5	1.4	0.7	68.5	3xR-	2xH+ 2xH
Map 2	4.6	11	4	1.1	21	3.2	15.1	7.3	17.1	2.1	0.1	18.6	5.4	1.8	112.4	1xR+ 4xR 1xR-	2xH+ 3xH
Map 3	4	14.2	5.6	1	21.3	2.1	16.1	5	14	0	0	21.2	7.6	5	117.1	1xEA- 1xR+ 1xR 2xR-	1xH+ 5xH
Complex Knowledge			14.7							3.1			21.9		39.7	14xR	15xH
Total		59.7						164.1					74.2		**298**		
Class Web Files	21	6	8	1	854	199	328	151	337	185	19	33	2	8			
Complex Knowledge			9							204			10		223	2xR	1xH
Total		36						2073					43		**2152**		
															2450	**16xR**	**16xH**

Note: 1 = Total units of knowledge

English x1 = 6 teaching months integrated technology use; *English x2* = 14 teaching months integrated technology use
English x1 n = 22 students. *English x2 n* = 19 students.
Numbers represent the mean of all scores generated for the class.
SOLO rating: EA = extended abstract, R = relational, MS = multistructural, US = unistructural
+ = Top third of level; – = lower third of level.
Design rating: VH = very high aesthetic appeal, H = high aesthetic appeal, M = medium aesthetic appeal, L = low aesthetic appeal.
+ = Top third of level; – = lower third of level.

Perhaps of more significance is the observation that *English x2* (262.7) generated almost twice as many instances of more complex understanding than *English x1* (139.7). There was minimal difference between the two classes for more complex nodal types (relational and extended abstract), but the means for other attributes indicate larger differences. For example, *English x1* (8.1) scored over twice as many instances of more complex thinking in nodal content (relational thinking and extended abstract) than *English x2* (3.1). This would suggest more effective associational thinking and synthesising of information for *English x1*. However, it is the explanatory and elaborative linking that indicates the level of relational association and cognitive consolidation and thus the complexity of understanding. In using this perspective, *English x2* (21.9) almost quadrupled that of *English x1* (5.8).

Even with Web files, *English x2* generated more total units of knowledge (2152, with 10 instances of more discriminating linking) than *English x1* (932, with 0 instances of more discriminating linking). An appreciation of the students' development of more discriminating linking from map one to map three can be gained by comparing the frequencies of structural and elaborative links. *English x1* demonstrated minimal difference in explanatory linking from concept map one to three (1.3–1.1), while *English x2* demonstrated steady growth (1.4–7.6). A similar pattern is evident with the elaborative links for *English x1* (0.2–1.1) as less than for *English x2* (0.7–5). Overall *English x1* generated 102 structural links, many of which were internal links on the same Web screen, but no higher order links in their group Web files. *English x2* generated only 33 structural but 10 higher order links that suggests greater focus on associative rather than structural linking of their Web nodes.

An examination of the SOLO and design columns reveals other notable differences. Overall *English x2* scored 16 relational ratings (R) which indicates quite complex representations of knowledge for the class, as against 12 for *English x1*. In terms of design ratings, however, *English x1* scored over twice (38 H) that of *English x2* (16 H). When SOLO and design results are considered in tandem, they indicate the degree of consolidation of understanding reflected in the pattern of the organisational structure of knowledge. From this perspective, the SOLO and design levels correlate more evenly for *English x2* (16, 16) than for *English x1* (12, 38). This variation could indicate that students had concentrated more closely on either the technological operation or the critical, cognitive purpose of their tasks. For example, *English x1* students seemed more focused on achieving an aesthetic appearance for the map whereas the design levels for *English x2* focused more on knowledge consolidation to make a rich text.

As the academic ability of both classes was initially similar, all these differences might be partially explained by *English x2* 's lengthier exposure to collaborative, computer-mediated learning processes where their familiarity with the software and their practice with the strategies reduced cognitive load.

7. Discussion

In this instance the technoliteracy model would seem to have facilitated the integration of technology skills, computer-based cognitive tools and literacy practices through students' engagement in the design of electronic representations of understanding. The complex interrelatedness of collaborative learning, active negotiation of meaning through group discussion and construction of representations of knowledge on the computer would appear integral to the nature of learning in a computer-mediated environment. Thoughts were generated which might not have been possible without the collaborative discussions using the electronic cognitive tools (Jonassen, 1992; Scrimshaw, 1997) and students were engaged in deeper processing of the information (Mayes, 1993). These conclusions were drawn from observations of the differences between frequencies of lower order factual/structural information and higher order relational thinking as manifestation of complex meaning-making.

In this instance, student-designers seemed to move to deeper levels of understanding through collaborative focus and discussion with knowledge-creation software. In so doing, the agency of design served not only to apply technology skills to the manipulation of ideas but also to foster deeper, more critical thinking about content. Several related factors emerged in relation to the student-designers' generation of electronic texts.

Perhaps one key factor influencing student success as designers of meaningful knowledge structures could be time-related. Results in Table 2 suggest that small doses of exposure to computer-mediated experiences do not produce comparable SOLO levels to those where coherent, prolonged, integrated exposure predominate. Perhaps the degree of correlation between the levels of design and SOLO levels could be explained via two fundamental issues.

The correlation of design and SOLO ratings for *English x2* indicates that a longer period of exposure to technology could be associated with the students' development of complex understanding. With longer exposure to integrated technology usage, technological proficiency requires less mental or emotional expenditure, allowing greater focus on developing complex understanding. In other words, the technology itself becomes almost invisible, an accepted medium through which the learner can develop ideas and represent knowledge.

Secondly, as indicated by the design and SOLO levels for *English x1*, minimal exposure to technology usage seems to reflect learner concentration on manipulating the software/fascination with design at the expense of intellectual rigour. Table 3 suggests that *English x1* students seemed to concentrate on perfecting their designs from the first map, but at the expense of the intellectual depth of their representations. By contrast, the relatively high correlation between design and SOLO levels for students in *English x2* would suggest that their confidence with the software and use of technology in general allowed students to focus on the intellectual challenge of the task from the beginning. As their understanding deepened and their conceptualisations consolidated, the quality of design improved proportionally. With their familiarity with the digital environment and their collaborative endeavours, these learners seemed more intent on developing their knowledge representations than playing with or having to learn the software in the early stages of the task. The Web file creation also illustrated a more applied purpose for technology skill acquisition than discrete technology skill development lessons.

The students' creation of their Web files for the intranet illustrated the way in which their communal, electronic desktop articulated the new writing spaces of their digital environment (Bolter, 1991) and was used as a problem-solving space (Jonassen et al., 1999). Here the students applied both their cognitive and technological skills to the co-authoring and refining of their electronic text as they developed and clarified their collective and individual understandings. The overt physical effort required to construct the various components of the Web files reinforces the networked knowledge-building process, and articulates the generative learning process as students see their knowledge corpus build incrementally over time. Certainly the students' increased levels of understanding as shown in the concept maps and possibly the Web files could have developed as a consequence of their added familiarity with the software as much as their deeper reflection on the topic. All these points appear contributory to the development of more robust understanding of subject content through the students' generation, re-generation and consolidation of their understandings.

These findings suggest that these student-designers had successfully extended their levels of cognitive understanding of the subject content through their collaborative discussion mediated by knowledge-creation tools. The students' active, constructive, collaborative and reflective methods of working seemed to exemplify other researchers' views of meaningful learning with technology (Jonassen, 1992, 1995; Jonassen et al., 1999; Light & Littleton, 1999; Reader & Hammond, 1994; Scrimshaw, 1997; Underwood & Underwood, 1999). By encouraging students to focus on the task as architects of knowledge and designers of a website, these technoliterate student-designers had become creators of knowledge and not mere consumers of information (Jonassen et al., 1999; Lehrer et al., 1994; Scrimshaw, 1997).

Overall these findings suggest that these senior humanities students responded to the challenge of becoming student-designers of electronic representations of knowledge. The analysis of the artefacts has illustrated how the criteria templates facilitated discrimination between levels of thinking in multimodal texts. It has generated a detailed appreciation of what technoliteracy might mean in practical terms for teacher-designers of curriculum-based, computer-mediated units of work for fostering the development of their students as technoliterate learners.

8. Conclusion

In exploring the effectiveness of collaborative engagement with electronic knowledge-creation tools, this article has reported on the design of criteria templates suitable for distinguishing instances of complex thinking in multimodal texts. Results indicated the incremental and possibly time-related increase in sophistication of understanding associated with technoliterate practices. Future research into the processes of collaborative learning with technology could provide further insights and refinements to these evaluative tools.

With sustained integrated technology use throughout the years of schooling, every student would be exposed to experiences where they acquire not only technological proficiency but also balance between their design abilities and depth of knowledge. If the integration of technology into curriculum areas is to move beyond mere embedding of discrete skills, every effort should be made to ensure that students are given opportunities to work collaboratively with electronic knowledge-creation tools in their learning process to enhance their learning. When students are encouraged to externalise their mental schemas and clearly communicate their understanding of the interconnectedness of ideas verbally and graphically, then student-designers are effectively engaged in productive, reflective, creative technoliterate practices.

Appendix A. Evaluative criteria for Web screens

<table>
<tr><th></th><th>Extended Abstract</th><th>Relational</th><th>Multistructural</th><th>Unistructural</th><th></th></tr>
<tr><td>Nodes
Unit of information - could be factual, interpretive, defining concept</td><td>A number of screens are created, revealing some discrete screens but generally detailed understanding of relationships between aspects of topic, and evidence of multiple perspectives.
+ | -</td><td>A number of screens are created, developing detailed understanding of both discrete and related aspects of topic
+ | -</td><td>A number of screens are created of generally discrete aspects of topic in some detail
+ | -</td><td>Only one node- no branching noted
+ | -</td><td rowspan="2">Content</td></tr>
<tr><td>Factual and Interpretive Detail</td><td>Strong evidence of analytical and critical thought, with examples of thinking from different perspectives or isolating sophisticated concepts or relationships
+ | -</td><td>Onscreen text is generally factual or descriptive but evidence of synthesis, relating different aspects eg textual or historical evidence for a statement.
+ | -</td><td>Onscreen text is mainly information, fact or descriptive detail
+ | -</td><td>Minimal onscreen text. Discrete blocks.
+ | -</td></tr>
<tr><td>Internal Links
Indicate strength of relational understanding (includes ease of navigation)</td><td>Linking includes structural, explanatory and elaborative, both between screens and within the one screen
+ | -</td><td>Linking is mainly structural but includes explanatory or elaborative. Can include target links (structural or explanatory) within one screen.
+ | -</td><td>Linking is structural, mainly from one index screen with no or few links within one screen
+ | -</td><td>No linking
+ | -</td><td rowspan="2">Organisation</td></tr>
<tr><td>WWW Links</td><td>WWW links synthesised into onscreen text, with addition of some interpretive comment by student author/s
+ | -</td><td>Some WWW links, synthesised into onscreen text.
+ | -</td><td>Minimal WWW links. Isolated usage.
+ | -</td><td>No WWW links utilised.
+ | -</td></tr>
<tr><td>Aesthetic Appeal

Artistic impact - balance, proportion, colour combination</td><td>Web site shows meticulous attention to choice of colours, significance of colour combinations, use of graphics/audio files.
+ | -</td><td>Web Site shows close attention to significance of colours and related graphics/audio files. Reasonable level of integration and consistency of pattern of colour/graphic usage
+ | -</td><td>Web Site shows some attention to choice of colours and design of layout. Graphics/ sound files may be used but not necessarily synthesised or relevant to onscreen content.
+ | -</td><td>Web Site colours unrelated to thematic content of onscreen text.

Minimal use of graphics - unrelated to thematic content.
+ | -</td><td rowspan="2">Design</td></tr>
<tr><td>OVERALL</td><td>Complex but clearly differentiated site. Detailed information, very well synthesised, showing awareness of different perspectives or viewpoints
+ | -</td><td>Quite a complex site with clearly differentiated sections. Detail well synthesised with close attention to relatedness of information.
+ | -</td><td>Site may approach complexity but information is mainly descriptive/factual, with little attention to relatedness.
+ | -</td><td>Simple site
+ | -</td></tr>
</table>

Note: Criteria scoring criteria based on SOLO taxonomy. Descriptors represent middle of the range comments.

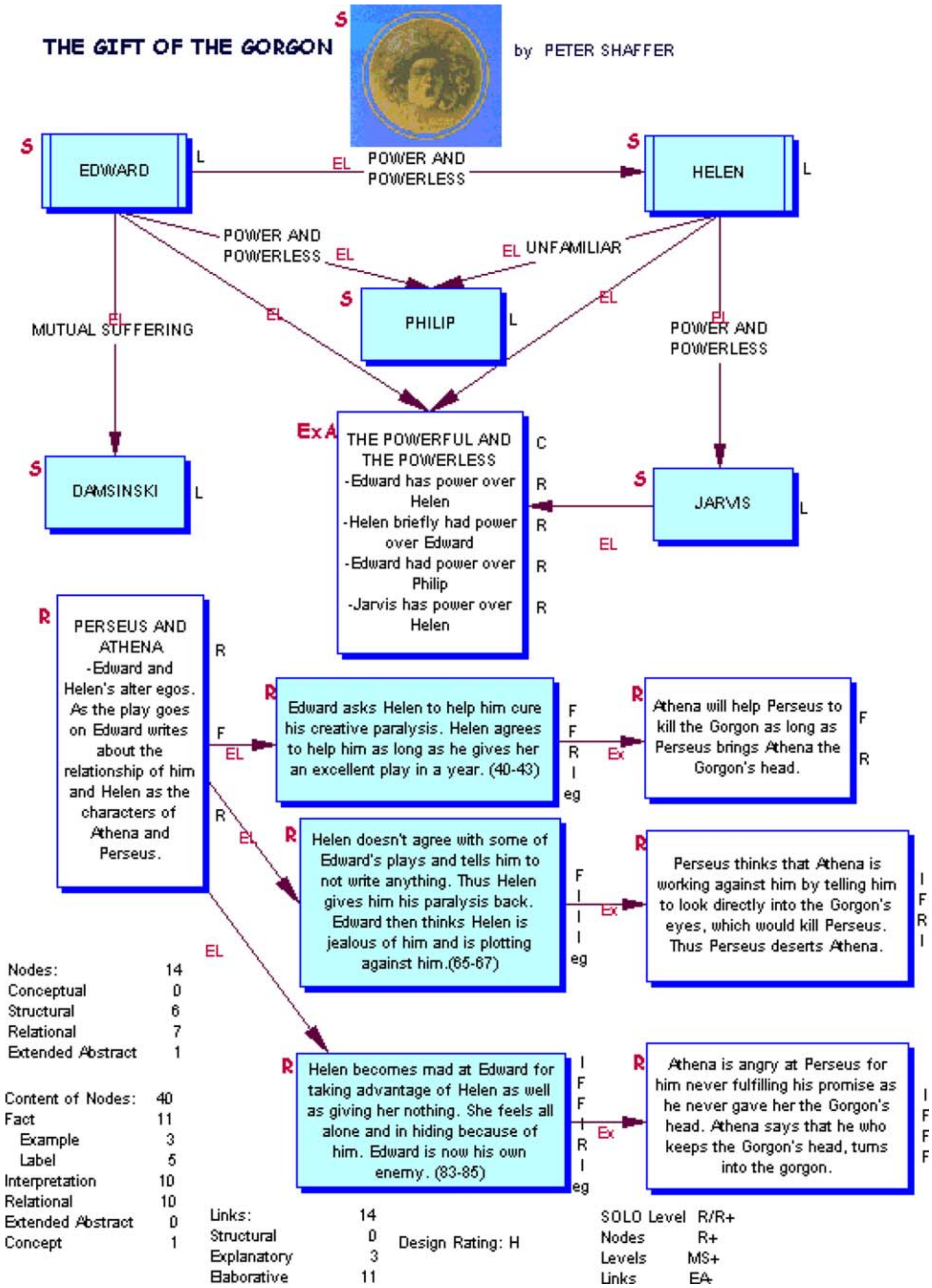
Appendix B. Scoring criteria evaluative template for concept maps

<table>
<tr><th></th><th>Extended Abstract</th><th>Relational</th><th>Multistructural</th><th>Unistructural</th><th></th></tr>
<tr><td>Nodes
Unit of information - could be factual, interpretive, defining concept</td><td>Organisation of nodes includes same features as for relational, with the addition of different perspectives on concept focus.
+ | -</td><td>Most nodes are correctly identified, frequently branched and most, correctly linked.
+ | -</td><td>A number of nodes or concepts are correctly identified, usually isolated on terrain; some of nodes can show branching
+ | -</td><td>Only one node is identified - no branching noted
+ | -</td><td rowspan="2">Content</td></tr>
<tr><td>Levels/ Hierarchies</td><td>Over three levels or hierarchies are correctly identified, linked, crosslinked and seen from different perspectives
+ | -</td><td>Over three levels or hierarchies are correctly identified - with links and some crosslinks.
+ | -</td><td>At least three levels or hierarchies are correctly identified
+ | -</td><td>No levels or hierarchies of concepts are identified
+ | -</td></tr>
<tr><td>Categorising concepts</td><td>Correctly identified superordinate concepts are linked and crosslinked - representing different perspectives
+ | -</td><td>Correctly identified superordinate concepts are linked and crosslinked
+ | -</td><td>At least two superordinate/ Subordinate concepts are correctly identified
+ | -</td><td>No categorising concepts are identified
+ | -</td><td rowspan="4">Organisation</td></tr>
<tr><td>Colour or symbol differentiation</td><td>At least four appropriately coloured or nodal shapes used, signifiying different perspectives
+ | -</td><td>Between three and five appropriately coloured or nodal shapes used
+ | -</td><td>At least two different coloured or nodal shapes appropriately used.
+ | -</td><td>One colour or nodal shape used.
+ | -</td></tr>
<tr><td>Links
Indicate propositions - strength of relational understanding</td><td>Appropriate linking, attention to directional flow, more subtle naming
+ | -</td><td>Appropriate linking, attention to directional flow, appropriately named
+ | -</td><td>Some appropriate linking, usually one way, usually named, if rather basically
+ | -</td><td>None or one way only
+ | -</td></tr>
<tr><td>Crosslinks
Operate between levels</td><td>Many crosslinks appropriately named and directional
+ | -</td><td>At least two crosslinks, appropriately named and directional
+ | -</td><td>No crosslinks identified
+ | -</td><td>No crosslinks identified
+ | -</td></tr>
<tr><td>Aesthetic Appeal

Artistic impact - balance, proportion, colour combination</td><td>Groupings show close attention to balance, proportion and palatable combination of colours. Extra symbols with obvious intent and relevance are used.
+ | -</td><td>Groupings show some attention to balance, proportion and palatable combination of colours. Extra symbols with obvious relevance are used.
+ | -</td><td>Groupings show little attention to balance, proportions or palatable combination of colours. Extra symbols used, with occasional appropriateness.
+ | -</td><td>Little attention to balance, proportions or palatable combination of colours.
+ | -</td><td rowspan="2">Design</td></tr>
<tr><td>OVERALL</td><td>Complex but clearly differentiated site.
+ | -</td><td>Quite a complex site with clearly differentiated sections
+ | -</td><td>Site is clearly distinguishable
+ | -</td><td>Simple site
+ | -</td></tr>
</table>

Note: Criteria scoring criteria based on SOLO taxonomy. Descriptors represent middle of the range comments.

Appendix C. Frequencies of coded details: individual electronic concept map (Stage 3)



Note: Explanation of Coding: *Content of Nodes:* F (fact) = "gave her the Gorgon's head"; L (label) = "Edward"; I (interpretation) = "becomes mad"; C (concept) = "powerful"; R (relational thinking) = "Jarvis has power over Helen". *Nodes:*(to top left of node): S = Structural, C = Conceptual, R = Relational Nodes. *Links*: S = Structural.

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