

COMPARING LEARNERS' CONSTRUCTS USING "SOCIO-NETS": AN APPLICATION OF REPERTORY GRID ANALYSIS

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Abstract

Repertory grid analysis was employed as a means of constructing representations of learners conceptions of living things (described in previous work). Experts in biology and secondary school science learners were probed for their representations of living things. Clearly, a theory is at work in the mind of the experts. The question now is: how many of the students share this theory? A record of commonality is required, and for that a social network framework is necessary. Therefore, representations were compared using the SOCIO program which measures the similarity between individuals and a visual network produced for the groups studied. This work is part of an overall project examining the learners' innate ability to classify and categorize living things. Classification and categorization are neglected in science curricula which has implications with respect to the renewed emphasis in education on learning about biodiversity. It was found that whereas there is a commonality with respect to learners' conceptions, the commonality is measurable and that learners often operate within a 'pre-scientific' or folk-biological mode, experts operate within a highly formalized mode based on their training, and that notwithstanding such a difference in modes, there remains a degree of commonality between learners and experts.

Key words: repertory grid analysis, socionets.

Introduction

"Human life is social life"

(Müller, Carpendale, Budwig, & Sokol, 2008, p. 1)

McCloughlin & Matthews (2009) examined the structures of representations of secondary students' construing of living kinds using Repertory Grid Analysis (Kelly, 1969, 1992; Shaw, 1980; Shaw & Gaines, 1995; Slater, 1972, 1977). In that work, a simple matrix composed of scores, ratings or ranks produced principal components plots which are a graphical representation of the individual student's constructing of concepts. Furthermore, cluster analysis based on the same grids allowed hierarchical classificatory dendrograms to be produced. Thus, in line with the original intentions of the progenitor of Repertory Grid Analysis (Kelly, 1992), the internal mental construals of a person may be examined and feedback can be given in order to assist a change to the constructions. Having demonstrated the feasibility of such in-

ternal elucidation, it behoves the educational researcher to seek an overall social aspect, since, as part of the social-constructivist (Leach & Scott, 2008) project, the social aspect of learning is important and much learning takes place within a social context such as schooling. This ultimately derives from Vygotsky's (1978) sociocultural view of learning that high level mental functioning in the individual is a component of the social life of the individual. As Berger and Luckmann (1966, p. 49) stated, as soon as one observes phenomena that are specifically human, one enters the realm of the social. Social construction is one of the 'five pillars of wisdom' of the Cognitive Acceleration through Science Education (CASE) project which seeks to combine the social constructivist approaches of Jean Piaget and Lev Vygotsky. For the biology educator and learner, constructivist approaches to learning about living things can be problematic. According to von Glasersfeld (1995) learning is not a process of acquiring ready made entities of knowledge and that purely objective knowledge does not exist fully formed external to the learner, rather "knowledge is [...] actively built up by the cognizing subject" and "the function of cognition is adaptive; and serves the organization of the experiential world, not the discovery of ontological reality". Human knowledge of living things is constructed, and highly personalized, and whereas there are biological facts which exist about living things external to the learner the present work seeks to acknowledge that rather than giving learners questions and examining them on whether they are 'right' or 'wrong', the professional educator will rather examine the measurable quality of similarity between the learners constructs and the teacher's. Only then can informed and evidenced-based remediations take place, otherwise the learner continues to be blamed for any shortcomings in their knowledge and the onus wholly on them to improve.

Learning about living kinds, a special subset of natural kinds (Gelman & Markham, 1987), owes in some part to enculturation. However, each culture forms an understanding of living kinds that serves the culture the human happens to be acculturated albeit within an indigenous Amerindian, a 'Westerner', or a biologist (Atran, 1999). Ethno-biological research has examined the differing taxonomies of Western tutored biology learners versus those of tribal indigenous groups and the folk-botanical knowledge of these tribal groups has been extensively analyzed (Atran, 1999; Berlin, 1992, 1999; Berlin, Breedlove, & Raven, 1974; Medin & Atran, 1999). It is evident that tribal indigenous groups possess taxonomies and classification systems that are as rich, and comparable to, formal scientific systems. Human children become cultural beings by learning to participate in the cultural activities and practices going on around them (Behne et al., 2008). In addition, if those cultural activities are disrupted, then the intellectual knowledge associated with the culture also diminishes, so for example, Irish children have a much poorer ability to name plants and animals now than a generation ago. Whence the cause of disruption? Ironically, as people become better educated, people tend to know less! The modern Western European can operate a bewildering array of electronic devices, engage in advanced social networking, and enjoy sophisticated foods and complex forms of entertainment. However, the modern European's ability to make composite foodstuffs, understand the role of the seasons in the cycles of nature (and where one's food should fit into this), to be able to distinguish native fauna and flora from 'aliens' and understand why this is important, and be able to name five animals and plants in any one ecosystem is proving more and more elusive. The knowledge areas mentioned here are in the realm of 'folk' knowledge, whereas the use of electronic equipment, computer games and social networking are in the realm of 'technology'. Because of this purported disruption to folk learning, it is necessary to examine the 'distance' between the learner and an expert – the teacher perhaps. In this study, we examined the similarity between two experts in biology and class groups of learners. However, examining the development of constructs within a group and obtaining a feeling for the commonality or coherence of constructions within a group can be difficult to establish. Nonetheless, credible assessment of a group of learners can only be done if a reference point is obtained and some understanding of how a group behaves or thinks in relation to a probe before such a probe can

be used as an assessment item. McCloughlin & Matthews (2006) examined similarity of grids within large groups of students in terms of taking the simple matrices or grids and subtracting them – a simple function of matrical arithmetic which would be sufficient on an individual basis of determining the 'distance' between a teacher's conception and a single student's. Averaging whole class groups' sets of grids was also done to consider the combined mental structure of the class group. Such a combined mental structure is a construct of the mathematics of the program used to carry out this feature. In this present work, we examine whole class groups and measure the similarity between each person in the group and plot these similarities as links on a web diagram with each participant as a node on the web.

Methodology of Research

Two sets of six equid images (Figures 1 and 2) were presented to secondary school students (N=110) over five year groups out of six in a large community school in Ireland. A community school is an inclusive non-denominational and mixed gender school. Secondary Schooling in Ireland is from 12 until 18 years. The equines that were chosen were a mixture of familiar, less familiar and fictitious taxa. They were quagga, zebra, horse, the appaloosa breed of horse, the melanic zebra and the speckled zebra in the first set (Figure 1); and melanic zebra, dartmoor pony, mountain zebra, mesohippus, quagga and eohippus in the second set (Figure 2). The shape, size and habit (i.e., poise) were factors, which were kept constant; in fact, all of the equines were produced from an altered 'bitmap' of the zebra. The key features and rationale for inclusion of the specific examples are given in Table 1. An exhaustive list of features was presented to the subjects who had to choose a feature that best described the first animal; another feature that best described the second and so on. They then had to rank each feature in turn with each animal thus again producing a matrix of six columns by six rows. The investigator entered all the grids obtained into RepGrid 2.1 (Shaw, 2009) manually.

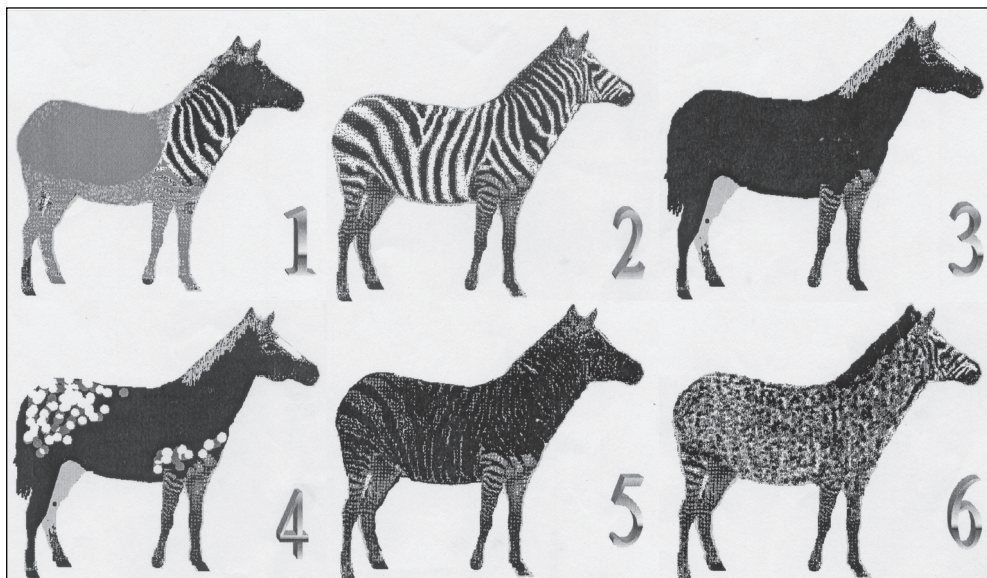


Figure 1. The first set of equids.

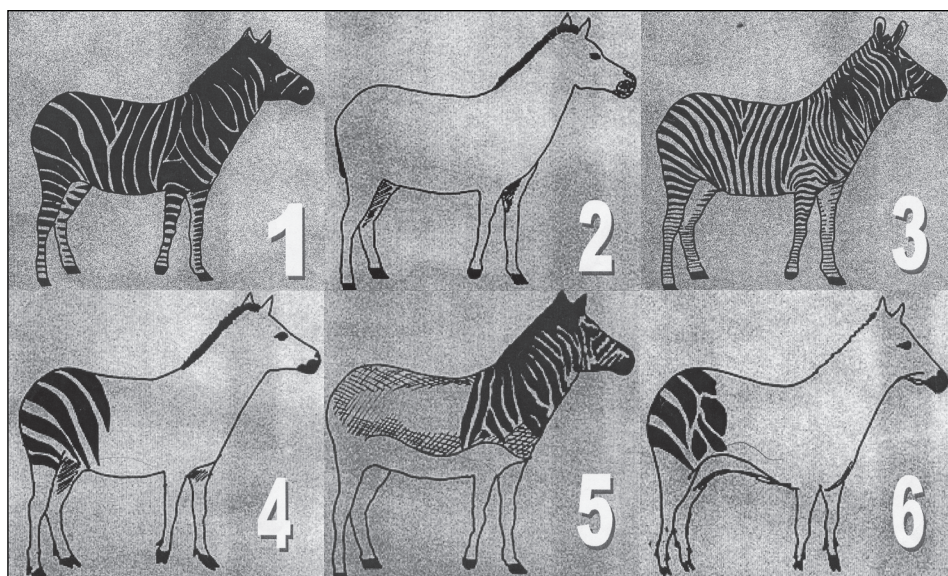


Figure 2. The second set of equids.

Table 1. Descriptions of the images in the equid study.

Set	English Name	Latin Binomial	Graphic Style	Rationale for inclusion
First	Horse	<i>Equus caballus</i>	bitmap	this is a stereotype of an equid, a basic example but with stripes on its leg
First & Second	Melanic zebra	<i>Equus burchelli</i>	bitmap & cartoon	a rare form of plains zebra resulting from a genetic state which caused a large deposition of melanin in the coat of this individual.
First	Speckled zebra	not applicable	bitmap	an imaginary equid
First	Plains zebra	<i>Equus burchelli</i>	bitmap	this is a stereotype zebra, the common image of a zebra
First & Second	Quagga	<i>Equus burchelli quagga</i>	bitma & cartoon	a subspecies of the plains zebra. It is extinct at present but attempts are being made to 'resurrect' this subspecies.
First	Appaloosa	<i>Equus caballus</i>	bitmap	this is a north American breed or horse with distinctive coat markings that appears counter intuitive to Europeans
Second	Dartmoor	<i>Equus caballus</i>	cartoon	an ancient breed of horse of a shape and habit that humans would have been more accustomed to than 'modern' thorough-bred types
Second	Mountain zebra	<i>Equus zebra</i>	cartoon	a zebra that appears to the untrained eye to have extra stripes
Second	Eohippus	<i>Hyracotherium</i>	cartoon	extinct, a small horse like animal with multiple toes about the size of a large dog
Second	not applicable	<i>Meshippus</i>	cartoon	extinct, a relatively small horse but with cloven feet

A sequence of socio-metric diagrams called socionets in the part of RepGrid 2.1 called SOCIO are produced from the matrix of similarity measures between pairs of individual grids. The highest related pair is picked out initially as a sub-group, followed by the sub-groups defined by the rank ordering of all similarity measures. A number of choices must be made with SOCIO, not least whether the user wishes to view the output of the comparison in a textual or graphical format. In the textual format, a number of criteria for the comparison can be checked, and in this thesis, the author consistently checked the boxes, 'grids' and 'links'. Once the required grids are opened and have been selected, similarity can be calculated between any two grids at a specifiable level of match. For much of the example described later, a match level of 80% was chosen, i.e., the percentage of the total maximum match was 80%. This value was chosen because experience showed that at lower levels, the number of links proliferated *ad absurdum*. The user has a choice of whether to have the output represented in a graphical (socionet) form or a text format. There are a number of options in the text based format: checking the 'grids' option leads to the output which is in effect a list of the input data.

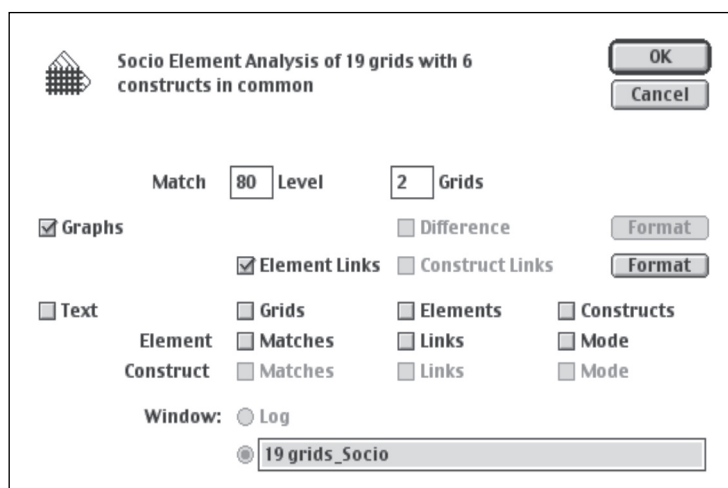


Figure 3. Parameters of SOCIO.

Checking the box in Figure 3 for 'matches' provides an output similar to that shown in Table 2. Table 2 shows the socio exchange output where the highest match from the second of any pair of grids with a closest match to each one in the first grid is shown, and vice versa. This occurs when, as in this case, only the constructs are in common. Two numbers appear in each comparison; one, a percentage, is a statement that that percentage of the matches have at least reached the desired 'level' – which is the second figure: a decimal figure denoting the level at which the match is calculated. In general, the higher the level figure, the more restrictive the parameters for allowing a match. The 'level' serves to exclude some of the data from a purely pragmatic point of view since an open comparison would be time consuming, cause issues concerning computer random access memory and processor speed. As it stands, the output in this section is, by all regards, huge and reading it, let alone analyzing it, time consuming. Table 2 shows only one pair of grids (G1 and G2) being compared, which in the end exhibits a low similarity (16.7% overall at a match level of 80). A match level is a percent value of the maximum match possible between the two entities, thus 16.7% at a match level 80 is much less than 16.7% at level 90. Level 90 is a more restrictive matching and creates fewer matches or links in a network. Six matches are listed for each of the constructs for G1 starting from construct 4 (C4) in both grids scoring a similarity of 16.7% (low) at a relatively high match level of 86.7; to G1C6 and G2C4 scoring 100% (high) at a low match level of 66.7.

Table 2. Socio Element Analysis of 2 grids in the first year cohort: element correspondence.

G1<:G2 16.7% over 80.0 (HM111 Element-correspondence-from GF111)	
1: 16.7% ≥ 86.7	G1C4: having a fallen mane / G2C4: having a fallen mane
2: ≥ 73.3	G1C3: having a tail with long hair / G2C3: having a tail with long hair
3: 50.0% ≥ 73.3	G1C5: having a tail with long hair / G2C3: having a tail with long hair
4: 66.7% ≥ 70.0	G1C1: having a prominent jawbone / G2C5: having a prominent jawbone
5: ≥ 66.7	G1C2: having stripes regardless of number / G2C2: having stripes regardless of number
6: 100.0% ≥ 66.7	G1C6: having a fallen mane / G2C4: having a fallen mane

Each pair of grids is compared in turn, construct by construct. For example one pair is G1 and G2; the comparison is not merely checking the occurrence of elements chosen in each grid but rather the ranks of each grid for this element. Construct 6 in each grid (speckled zebra) shows a very low similarity at 16.7% at a level of 93.3 because they do not have the same elements except two (having a horizontal body and having no mane at all) but with the same rank with the first element. In the G1C4 (appaloosa) to G2C2 (zebra) comparison, different constructs have the same element but it has been ranked '2' in the appaloosa and '1' in the zebra, thus this gains a similarity score of 50% at level 73.3. In the G1C1 to G2C1 (both of which are quagga) comparison, they have two elements the same, one with the same rank which 'earns' 100% similarity at a relatively low level of 66.7. The program calculates an overall similarity at the specified level (80) which in this case was 33.3%. The information from the comparisons can be represented in a graphical form known as a Socionet. This demonstrates in a simple way where the links between constructs exist by plotting the subjects as equidistant points in a polygon (where the number of apices equals the number of grids) and drawing a vector between the grids represented as points where a link exists at a specified level. The user selects this option on the SOCIO parameter window (Figure 3) by checking the graph rather than text option. If the level chosen is too high, there will not be many links made, and the converse is therefore true, too low a level and so many links are made to make the graphic unreadable.

Results of Research

The first years, 12 – 13 year olds

Figure 4 and Figure 5 show the socionets for the first year group for the first and second set of equids respectively. AN111 and PK111 have the most links with others, some reciprocal, some not. The people with no links are isolates. In Figure 4, the relatively high percentage linkage at a high level partitioned students who had no links with any other students and others who had a range of links to AN111 who had 9 links with other students, 8 of which were unidirectional towards AN111. AN111 appears to have functioned as a stereotype; however notwithstanding such an observation, the links demonstrate that 9 students had grids of 70% commonality with AN111 and AN111 in turn had 70% commonality with CM111. In the second set of stimuli (Figure 5), a much denser socionet is produced showing much shared perception if not understanding of the items in the stimulation; this is all the more marked given that the level

was lowered to 70.0 to attempt to see if a more open structure emerged, however, it did not until an even lower level was used, so low in fact that the percentage similarity was in effect a poor match level. The second set of pictures was certainly processed by the students differently than the first set.

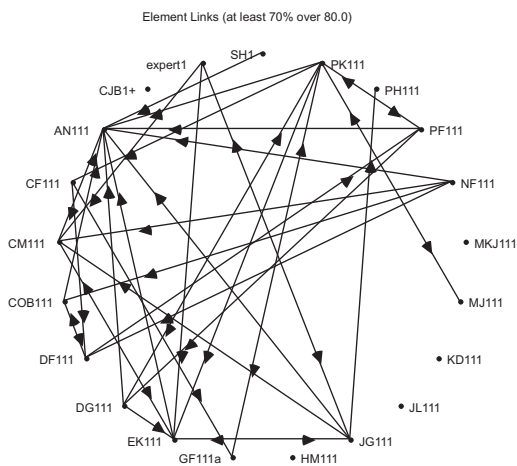


Figure 4. Socionet of first years: first set.

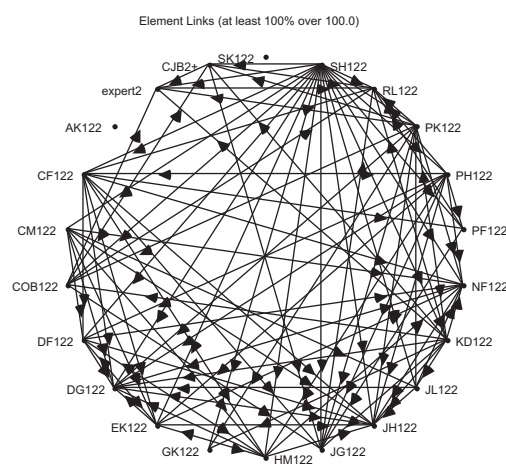


Figure 5. Socionet of first years: second set.

The second years, 13–14 year olds

The second year results (Figures 6 and 7) showed a high degree of consensus. In the 60% at level 90 socionet, a number of individuals had no connections with anyone else. ABr211 for some reason omitted one of the constructs, and used one of the elements twice. Thus, ABr211 may not have understood the task set, and EA211 had only two connections. ED211 and AM211 appear to be the stereotype for this group, because they have the greatest number of links (n=9). Note that both experts ('CJB' and 'expert1') are isolates.

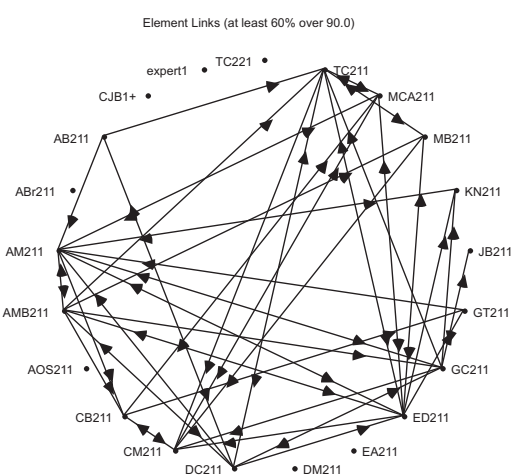


Figure 6. Socionet of second years: first set.

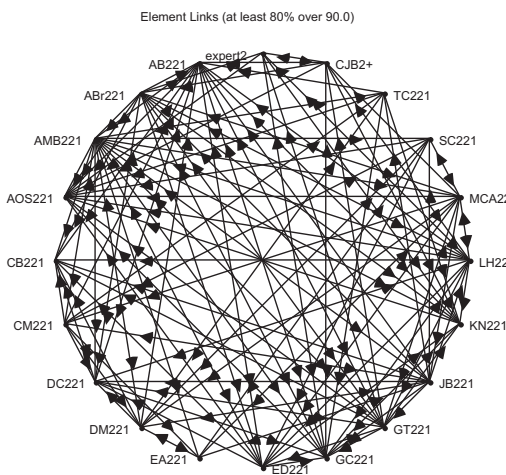


Figure 7. Socionet of second years: second set.

If we compare the sets of the second year students (Figure 6 and 7), the second set show a higher degree of consensus. We might assume that when a group of individuals cannot

achieve consensus “easily”, then the stimuli must be creating some cognitive conflict as indeed they were designed to do. The value of the repertory grid analysis is that it can detect such conflict within a class group and then the educator can refer back to the original grids or plots to determine the source of the conflict. In the second set (Figure 7) KN222 (whom is the same as KN221) appears to the stereotype.

Third years, 14–15 year olds

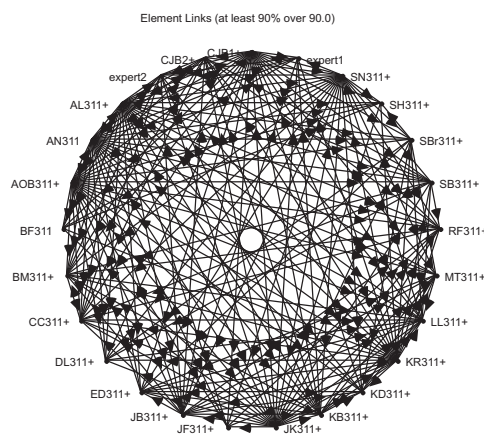


Figure 8. Socionet of third years: first set.

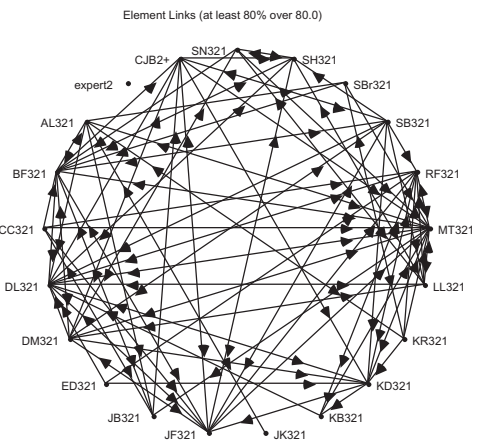


Figure 9. Socionet of third years: second set.

In the third year group, in the first set (Figure 8), a high degree of linkage was achieved at a relatively low set of constraint compared to the second set (Figure 9). This was also true for the fourth years (Figure 10) but it was even more marked that at a wide range of parameters, “confluent” (that is, it appeared that all students were linked to all others) linkage occurred indicating an almost uncanny similarity between the grids of the fourth year students. Note that ‘expert 2’ (the first expert) is an isolate also.

The Fourth Years, 15 - 16 year olds (elective)

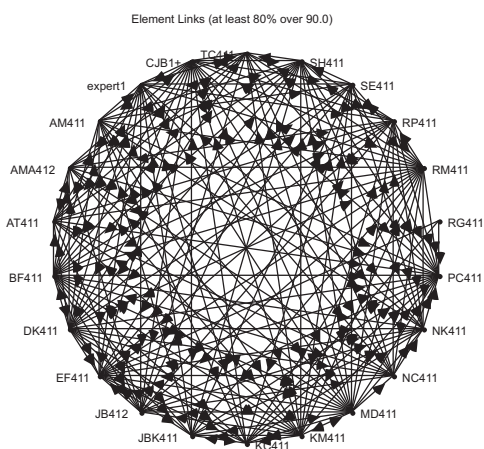


Figure 10. Socionet of fourth years: first set.

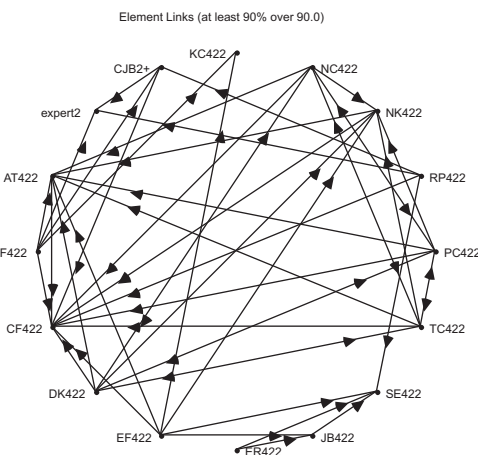


Figure 11. Socionet of fourth years: second set.

In the fourth year group, there is an almost identical perceived similarity of the first set of equids as evidenced by the same result over a number of parameters, (Figure 10). This not the case with the second set where a wide variety of interpretations exists among the students, hence a 'disparate' socionet at the lower set of parameters (Figure 11), however, relatively speaking there remains a high degree of commonality.

The Fifth years, 15 – 17 year olds

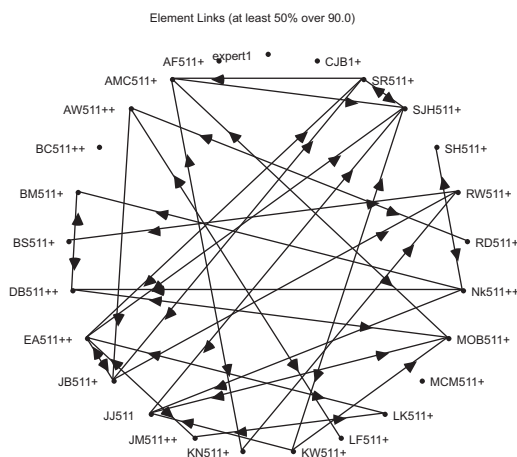


Figure 12. Socionet of fifth years: first set.

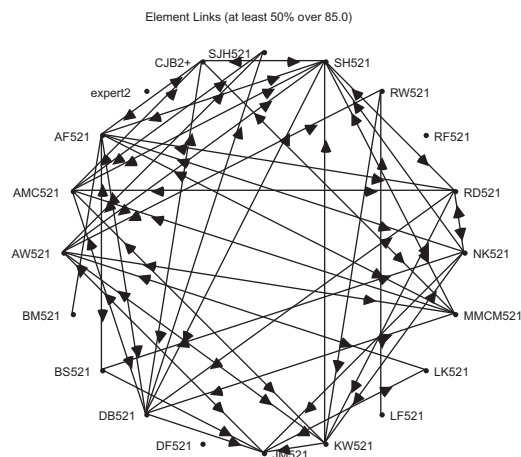


Figure 13. Socionet of fifth years: second set.

Here, we observe that the fifth years have a disparate understanding or perception of both sets of equids. It may be conjectured that whereas the second set of equids has caused a naïve theory to emerge since many of the pictures were of unfamiliar creatures, the fifth years now also seem to be individuating naïve theories concerning the first set of equids. Why this might be the case is unclear, however some peer influence may be at work.

Discussion

When educators teach, and learners learn, there is a need to examine the closeness of fit of the outcomes of both activities. The conception that the educator has constructed in their teaching should be replicated in the mind of the learner as a learned entity. Taking our cue from biological theory and informatics, measures of similarity between these two entities within groups of students were made and represented as socionets. Throughout the preceding socionet diagrams the experts were represented. We can tabulate the links (and thus similarities of a particular 'strength' and Table 3. shows the number of links that the experts share with the students. No developmental trend was evident: the experts did not appear to share much understanding of the constructs with the second and fifth year students as evidenced by the experts forming isolates at a relatively low socionet parameters. Whereas, the experts shared the same construct representations with the third and fourth year students' constructs in the first set of visual stimuli denoted in Table 3. as 'confluent'. Otherwise the experts did have a modest number of links in the remaining socionets, in general, during the administration of the second set of visual stimuli. Further research is necessary to establish why the fifth year students individuate more than, say, the third and fourth year students.

Table 3. Table comparing the number of links of the experts with other individuals.

	First expert biologist (denoted as expert1 in the first set and expert2 in the second set)		Second expert biologist (denoted by CJB1 in the first set and CJB2 in the second set)	
	First Set	Second Set	First Set	Second Set
First year students	3 links	6 links	Isolated	7 links
Second year students	Isolated	7 links	Isolated	9 links
Third year students	Confluent	Isolated	Confluent	9 links
Fourth year students	Confluent	3 links	Confluent	4 links
Fifth year students	Isolated	Isolated	Isolated	5 links

When a socionet is produced for a class group at the end of a learning sequence, its use lies in the comparison provided of comparing the teacher's conception with the students'. This creates the unusual, in some contexts, situation whereby the teacher would complete the assessment task alongside their students. When the teacher's conception appears isolated from most or all the students (see for example Figure 6 and 12), the educator should consider that the lesson has not gone well. When the teacher's conception appears part of a confluent linkage within a socionet (see for example Figure 10), the teacher can be satisfied that their instruction has resulted in a convergence of conceptions.

The fact that groups of students emerge as sharing an alternative conception and that the groups are defined by a calculated similarity, subjectivity is reduced in assessing the performance of both teacher and student. The teacher can hone in a particular group to examine why their conceptions are different and counsel the students in their work. Such a honing will require revisiting the original RepGrids of those students who demonstrate a low similarity with the teacher and identifying the specific point on which they differ.

Even when remediation work has been conducted to bring the learner's and the teacher's conceptions closer in similarity, the SOCIO program can be run again to determine the degree of improvement, since the parameters of similarity can be set differently. This post-remediation run of the SOCIO program does not have to involve all the students in the class but rather only the 'targeted' students, thus using SOCIO can help to monitor the progress of students.

Conclusions

This work demonstrates that similarity *per se* can be a useful tool in monitoring teaching and learning. The similarity between a teacher's and each of the students in a class group can be determined using the SOCIO program and displayed graphically at a range of parameters.

The use of socionets within a learning environment assists teachers observe whether students may individuate their conceptions and diverge from either their teacher or their peers; or, whether the students form clusters showing up alternative conceptions that form within a social context – as opposed to individuations. Monitoring remediation becomes possible therefore as part of an overall measurable objective assessment of student learning.

It is acknowledged that educators may be reluctant to use a program such as SOCIO in their work due to the complexity of the underlying principles. However, teacher educators can introduce techniques such as that described in this work in a small-scale situation, and it must be borne in mind that one of the present authors was a school teacher at the time of this study. Despite the complexity of the underlying principles, the execution of the SOCIO program is

relatively simple and to be commended to educators who wish to instill a certain level of measurable objective monitoring of small-scale learning at the conceptual level.

The socionets produced showed a relatively high degree of commonality and the relationship of the learners' conceptions could be investigated. Coupled with the original matrices of scores produced from the original instrument provides a set of powerful tools for the educator in investigating conceptual change / development.

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