An introduction to concept mapping in dental education: the case of partial denture design

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Abstract

The aim of this paper is to present concept mapping as a tool for enhancing clinical dental education and develops the authors' argument for the use of concept mapping presented previously in the pages of this journal. Materials presented are based on data gathered from extensive observation of learning and teaching in a UK dental school, and upon a case study of student learning of removable partial denture design. Using examples developed with students and teachers, critical elements of the approach are illustrated which can be used to support dialogue between the two parties. This approach can be used to develop active teaching strategies and engaged learning approaches that support the development of clinical expertise.

Introduction

Integrating theory and clinical practice has long been problematic for students of dentistry. Whilst university education is about developing creative, independent thinkers, this has to be reconciled with the need to ensure that a set of professional standards and competencies are met at some threshold level (1, 2). A dynamic expertise-based teaching approach places such a link at its core and will support students through the 'metamorphic changes in clinical practice' that are predicted for the near future (3). To facilitate such an approach to teaching, we recommend the application of concept mapping – a tool that supports the visualisation of learning and the manipulation of information.

Concept mapping

There is now a significant body of evidence to testify the power of concept mapping as a tool to summarise information in a way that can support conceptual change and assess understanding (4). Whilst this represents important benefits for student learning, the potential of concept mapping goes far beyond this. Concept mapping provides a trigger for the development of scholarly, student-engaged teaching (5), based on the visualisation of the elements of expertise (6). It is this greater potential that we wish to explore here in the practical development and implementation of a bespoke approach to teaching that reflects the professional values of the discipline. We encourage the reader to look beyond the implementation of concept mapping merely as a study skill tool to support the deficiencies of an outmoded content-delivery-based curriculum, towards an approach to teaching that grants students 'epistemological access' to the discipline (7–9).

Whilst concept maps are being more widely discussed as a tool in university teaching, the authors have previously noted that their impact on the dental education literature appears minimal (10). Concept mapping supports reflection upon the learning process by enabling the visualisation of change in student understanding, in qualitative as well as quantitative ways. As such, concept mapping provides an integrated mixed method that can be used to open a dialogue between teaching and learning in a way that is transparent. This is summarised as a concept map in Fig. 1, showing the links between the main elements of this article.

Concept mapping (11–13) is a graphical method that requires the learner to consider his/her understanding of a topic and the way in which the elements of that understanding fit together. It is the concepts (indicated in boxes in a concept map) that indicate the scope of the student's awareness whilst the quality of the links in a concept map convey depth of meaning. We have found that dental students are able to learn the mechanics of concept mapping in less than

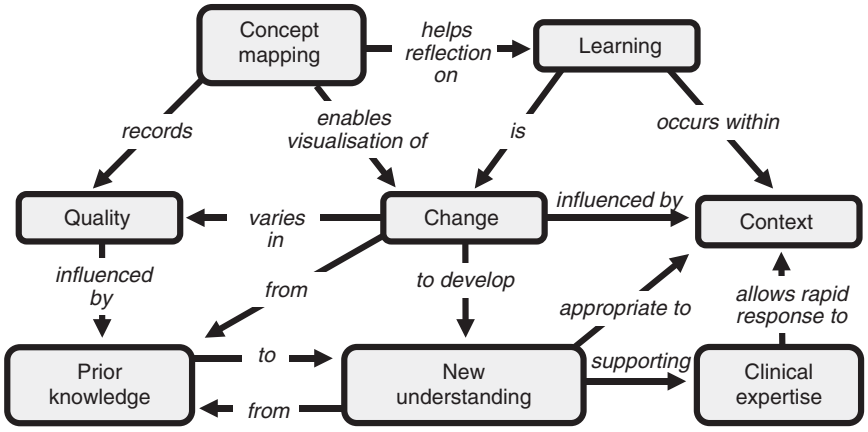

Fig. 1. A concept map to summarise the role of concept mapping in clinical education.

half an hour and are then ready to start producing their own concept maps.

The maps in Fig. 2 show the universal characteristics of concept maps (concepts in boxes, linked by arrows that carry explanatory phrases) and the typical morphological variations that will be found amongst a group of students (described as chains [A], spokes [B] and networks [C]). The significance of these morphological variations and the transformations from one to another are seen as having an impact upon the teaching and learning process. Unfortunately, many students embark upon their undergraduate studies with firmly established chains of understanding that are incomplete or inappropriate for their new educational context (5, 6). Such chains are resistant to development and so these students are faced with the dilemma of either trying to abandon their existing understanding and starting afresh or rote-learning the new material as an adjunct to their existing prior knowledge (14). Therefore, the promotion of spoke structures may be a good starting point for many bridging courses or university induction programmes as these are structures that can most easily accommodate additions and so facilitate the transition from secondary to higher education.

The chain [A] of appropriate understanding is indicative of *strategically successful learners* (students and lecturers) (5). These chains are exemplified by students who memorise comprehensive lists of facts for each topic and by those students who are well rehearsed in practical activities in such a manner that they know 'how', but do not understand 'why'. Such goal-orientation enables these learners to identify the essential information from that which is available whilst selectively ignoring the rest. This may be seen by some as an efficient way of studying whilst others could interpret this as a blinkered and unfortunate view of higher education that would not leave students receptive to further professional development.

The spoke [B] indicates a *learning-ready novice*, that is someone who can acquire new information for later integration without the need for radical restructuring of existing understanding. The spoke structure can accommodate new information, but the lack of integration means that the student holding

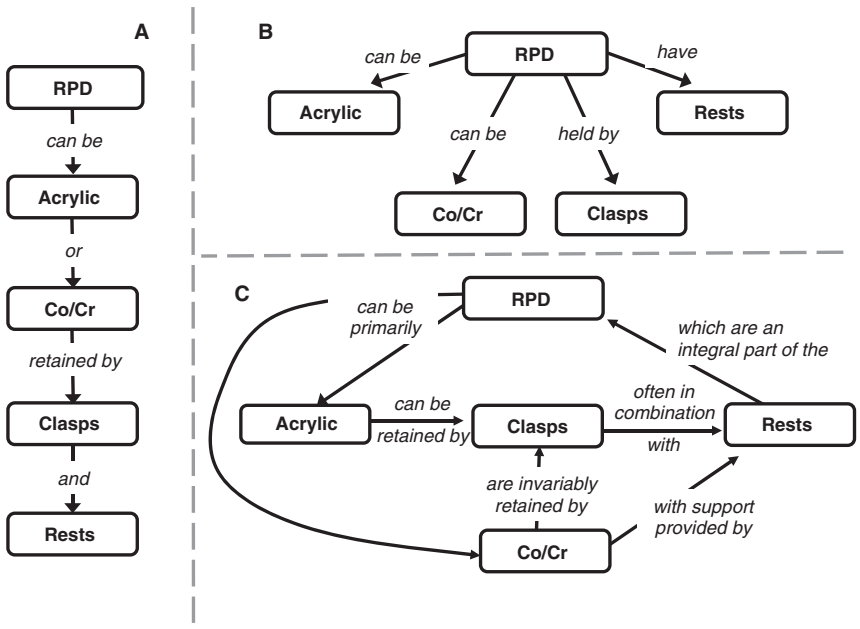

Fig. 2. Morphological variation in concept maps of the same information – removable partial denture design. Structural variation is indicative of the quality of understanding.

such a structure finds it difficult to appreciate links between concepts. For such a student, it would be difficult to interpret the dental programme as an integrated whole.

In contrast, the demonstration of highly developed and integrated nets [C] of understanding may be seen as the hallmark of an academic's expert understanding. For the academic, the demonstration of expertise is achieved by the accommodation of competing chains of understanding and the selection of appropriate chains to suit particular contexts. A particular chain of practice from an array held by the expert may be appropriate for use within a particular teaching context. The selection will depend upon the purpose of the session and the level of prior knowledge held by the audience. This is also seen when a clinical teacher is explaining a procedure to a students and then explains the same procedure to the patient using different terminology and intentionally neglecting uncertainties (7). So whether teaching is in a lecture theatre or in a clinical setting, the expert teacher will be able to choose which chain(s) to activate from within his/her underlying knowledge framework.

The quality of the linkages within a map is also a good indicator of the level of a student's understanding and his/her grasp of the appropriate terminology. For example, in the case of removable partial denture design (RPD), in the spoke-shaped map in Fig. 2 the concepts are linked by very simple terms that only indicate a loose association between the concepts. Two students who produce structurally similar concept maps may exhibit different levels of understanding based on the quality of linking statement (e.g. 'RPD *can be* Co/Cr' displays less depth of understanding than 'RPD *can be primarily* Co/Cr'). The student with the more sophisticated links is probably better placed to develop integration within the concept map. For example, the proposition 'RPD *can be primarily* Co/Cr' invites the question, 'what else are they composed of ?'. Responses to this question suggest links between ACRYLIC and other materials yet to be placed in this map.

Whilst qualitative differences in linkages *can be observed* in maps that are structurally similar, such differences are *usually observed* between maps that are also structurally different. Structure and linkage quality often go hand-in-hand. Chain-type maps often incorporate compound links that only make sense when the chain is read as a whole (e.g. 'RPD *can be* ACRYLIC *or* Co/Cr', where the *or* only makes sense in the context of the previous proposition). This compound nature of the linking statements contributes to the difficulty that student have when trying to develop a chain structure. For chains to develop, they need to be related to complementary networks that provide an alternative perspective and suggest different linkages that help the student escape from the constraints of linear thinking. In other words, if the chain is all the student knows, s/he cannot draw on more information that would fill the gaps in understanding.

Learning as change

Central to the implementation of an expertise-based approach to teaching is the conceptualisation of learning as change; a process of development from prior knowledge to new understanding (Fig. 1). Ausubel (15) has commented that what students know already is the most important thing to identify before teaching starts as this represents the cognitive raw material that students have at their disposal to support further learning. However, teachers in higher education comment that in practical terms, it can be very difficult to access students' prior knowledge for the purpose of conducting a meaningful dialogue. Concept mapping provides the practical tool to make prior knowledge visible (14). Once in this form, students can share their understanding with their teacher, their peers or even reflect upon it themselves in a manner that was not previously practicable. Our experience with clinical dental students has been that they will engage with each other to discuss the merits of different concept map structures in ways that we have not observed with other classroom strategies.

Students embarking upon an undergraduate course will always have some prior knowledge of the field. This prior knowledge may be well constructed and appropriate to the context (in which case it will help the students' future learning), or it may be fragmentary and full of errors and misconceptions (in which case it will create an impediment to future learning). Making prior knowledge visible so that it is available for scrutiny will help the student to articulate the difficulties s/he may be having and provides a common language for students to share understandings with each other and with their teachers. It makes misconceptions easier to diagnose and helps to focus the teacher's attention to where it will be most beneficial.

Quality of learning

Expert knowledge structures are typically viewed as being elaborate, holistic and highly integrated (16). However, such structures do not develop quickly and must pass through various structural changes, before they would be recognised as expert (17). Reviewing the development of understanding, by having students produce concept maps periodically, can illustrate the paths that different students will take, and can reveal much about a student's motivation and ability. Crucially, the maps produced by students also show that learners do not always focus on the ideas as intended by their teacher (18).

Development of the structure of student understanding from a rudimentary starting point can be viewed along a number of trajectories (Fig. 3):

1 Elaboration of the initial spoke structure by adding more concepts that are linked directly to the central concept. The concepts remain isolated from each other with no cross-linkages being formed. The student is acquiring information, but not integrating it in a way that can promote understanding.

2 Adding chains of information to arms of the initial spoke structure. This is often indicative of rote learning where chains are mimicking the sequencing of information delivered in lectures. Such sequences may reflect procedural chains that are of value when undertaking routine clinical procedures, but chains are characterised by their lack of flexibility and the students' inability to modify a chain in the face of new understanding.

3 Adding linkages to the existing structure may indicate a deeper learning strategy where a student is trying to understand the material and find different ways of relating the elements within the map. In such cases, it is not always necessary to add

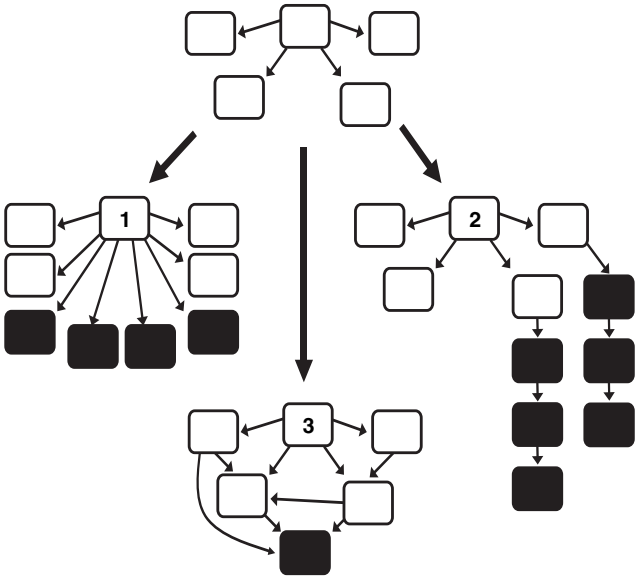

Fig. 3. Qualitative variation in learning, showing how development from an initial map of prior understanding can follow various structural trajectories: (1) acquisition of information without integration, (2) specialisation of information as isolated chains, (3) integration of information.

lots of new concepts to enhance understanding, but it is more important to develop the links between concepts. The tendency of many undergraduate courses of bombarding students with lots of new content may be less productive than developing understanding of material that has already been delivered.

An important aspect of the development of expertise is to maintain a balance between the development of chains (Fig. 3, part 2) and the elaboration of links (Fig. 3, part 3). The ability to oscillate purposefully between these structures is an indicator of expertise (7), and is suggestive of the sorts of conceptual exercises that could be employed to promote flexible thinking. Recognition of this provides teachers with a rationale for avoiding undue linearity in their teaching that can stifle creative thinking (10).

Student-engaged learning

For the teaching approach described to deliver the benefits that we predict, it is essential that students are actively engaged in their own learning and feel part of a community of practice, to which the students may contribute. This is another reason why we have found concept mapping to be the trigger for the successful implementation of an expertise-based approach to teaching. Throughout the extensive literature on concept mapping in teaching, researchers have commented on the high level of student engagement that is promoted by concept mapping activities (4). We have interpreted this through the literature that describes the learning behaviours that are promoted by certain teaching practices. So for example, whilst the repetitive use of PowerPoint in lectures can promotes passivity amongst students, concept mapping can have the opposite effect – promoting activity and engagement (10).

A student's (or teacher's) concept map of a certain topic invites comparison with other maps in such a way that interpretation requires justification and explanation. The conversations we have seen amongst groups of students (and groups of experts) are always highly focussed on the task, with participants taking ownership of their perspective (revealed through their map) and eager to debate the pros and cons of different knowledge representations. The idea that there may be more one right answer to a problem becomes self-evident during such discussions and helps to divert the strategic student from answer seeking behaviours that lead to surface approaches to learning. Anyone who doubts this should ask a group of students to concept map a topic that they (should) know well and then to compare and discuss their maps alongside their teacher's map. Invariably, the diversity of perspectives revealed by the maps generates animated discussion and exposes contrasting points of view.

The case of partial denture design

A teaching approach based on expertise strengthens the relationship between theory and practice by relating chains of practice to underlying networks of understanding (7). The design of RPD is a good topic in which to model this teaching approach as students often grasp the linear sequence of design, but have difficulty in relating this to an underlying understanding of design principles. A practical approach to support the integration of these two components of expertise is outlined here in the context of RPD design.

The construction of successful removable partial dentures (RPD) is not an easy task and central to this success is the development of an appropriate design. A lack of confidence in undertaking the design of RPDs may explain why this critical aspect of treatment is often left to the dental technician who has little knowledge of the patient and/or specific clinical issues (19, 20). It is also interesting to note that the design variables considered as essential by Lynch and Allen (21) were at variance with those presented by Frank et al. (22). This perhaps illustrates how difficult a subject this is, and explains, at least in part why some practitioners are uncomfortable with RPD design and the relative merits of each variable.

The authors have noted elsewhere (10) that the teaching of RPD design usually employs a number of integrated strands that are invariably presented and reinforced in a linear manner such as that presented in Fig. 4 (middle box). However, when students are asked to explain the links between these elements within this chain of practice, they find difficulty in verbalising anything other than a temporal sequence for the process. Students are often unable to explain how the chain is derived, how the elements relate to one another or indeed, how this chain relates to expert understanding of the subject.

Eliciting expert knowledge structures

The first stage in the implementation of a teaching approach based on expertise is the most threatening (or liberating) for those who are asked to teach – that is, eliciting the knowledge structures of the experts involved in the teaching. This is a vital

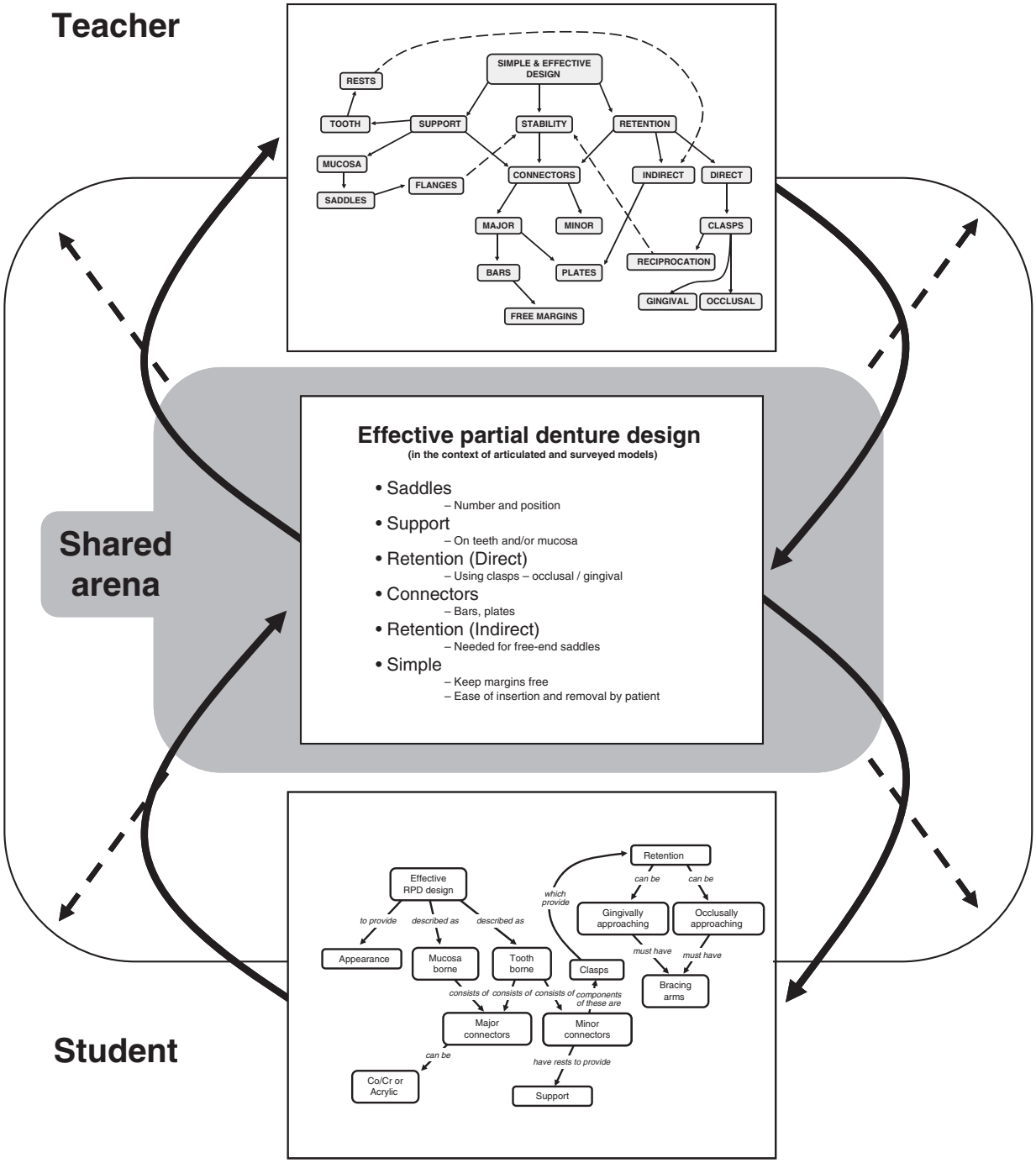

Fig. 4. An illustration of the way in which the expert's network of understanding (top box) is transformed into a teaching sequence that is placed in the shared arena (middle box), from which the student has to construct his/her own network of understanding (lower box). Expanding the shared arena (dotted lines) will allow students to see how the teaching sequence is derived from expert understanding and allow the teacher to see how the student starts to construct his/her understanding from the teaching sequence.

stage in the process as unless the teachers make their understanding explicit (to themselves and their colleagues), they are likely to revert to a routinised performance in which their expertise remains hidden. The tool we recommend to visualise such understanding is concept mapping.

Experts will often teach elements within an undergraduate course without ever comparing notes with their colleagues, under the false belief that they must agree on the nature of the basics that must be taught. Therefore, if as a first step educators have the courage to lay bare the diversity of their expert

knowledge structures, this will help to dispel the myth held by many undergraduate students that there is only one correct answer and once acquired, the job is done and learning can stop.

Stated so unambiguously, the idea that experts and the knowledge that they possess are all different seems obvious (23). But this is one occasion where stating of the obvious helps to clear the air and begins to help us understand why Lynch and Allen (21) were at variance with Frank et al. (22). This understanding now leads to a more profitable dialogue between expert teachers about the nature of the material to be taught. There will be diversity amongst expert knowledge structures, and in the context of RPD design this means that different experts are bound to attach differing levels of importance to defined design variables.

Mapping is an exceptionally useful tool to allow us to explore this expert knowledge. Figure 4 (top box) presents a map for successful RPD design as undertaken by a senior teacher of removable prosthodontics (the linking phrases have been removed for clarity). It can be seen quite clearly that this expert has placed Retention, Support and Stability at the centre of the map. In other words, he sees these three features as key factors to be considered in the development of a successful RPD design. The reader is also able to see the features that this expert considers as subordinate and how these are linked to the key elements. We suggest that it is almost possible to see how the expert is thinking through the sequence.

Another prosthodontist teaching a similar linear sequence to that outlined in Fig. 4 (middle box) will have a similarly complex network of understanding underpinning his/her knowledge; similarly complex, but different. And it is this difference that in part explains why undergraduates have difficulty organising their understanding of the subject.

Fortunately for the development of successful understanding, there will be a degree of overlap in the expert knowledge structures presented by two experts and in their perceptions of successful RPD design. It is this overlap that allows experts to function as a successful learning community of practice. Within this overlap will be found the core concepts that can be used to create structure for the student learning experience.

Scaffolding students' knowledge construction

The danger is to assume that once an expert has reflected upon his/her understanding depicted in a concept map, such as that in Fig. 4 (top box), that this can be presented to the student as the 'right answer'. Such an approach is likely to lead to a surface learning approaches being adopted by students. This might see them through short-term goals (such as the next examination), but it does not serve the profession well in the long term by producing dentists who have a commitment to continuing professional development – dentists who are able to learn and adapt their practice throughout their careers.

The relationship between the teacher and the student is summarised schematically in Fig. 4. The teacher possesses a complex network of understanding; this is transformed for teaching into a sequential chain of practice, and this is made public in the shared arena (the classroom and the teaching clinic). From this, the student is required to construct his/her own knowledge structure and typically s/he is then required to demonstrate his/her understanding by selecting the appropriate elements from the chain of practice, and indicate these at appropriate times to the teacher in the clinic and in examinations.

However, if it is only the linear sequence that is made available to the student in the shared arena, then both the student and the teacher are unable to see how the chain is derived from the other's underlying network. As we noted in an earlier discussion of the value of mapping as a learning tool (10), passing conventionally through the design stages of an RPD does not provide the undergraduate with an understanding of how the design variables interrelate or whether the completed design is necessarily appropriate for his/her patient. Nor if there are any flaws in the design, does it give the clinical teacher an insight into the undergraduate's understanding of the process that led to the flawed design. The teacher does not have access to the network of understanding on which the student chain is based. Studies comparing expert and novice understanding of complex systems indicate that novices tend to focus on the structures involved as they are more tangible, whereas the experts are more likely to employ a deep understanding of the functions of the elements to organise their understanding (24). This mismatch in organisation makes dialogue between novice and expert more difficult.

The teacher's task is made so much easier if s/he is able to visualise the undergraduate's developing conceptual model of the design process. Such a model can be seen in Fig. 4 (lower box). In the undergraduate's map the concept of stability is not one that features at all, yet it is clear that her teacher who was responsible for the map in the top box, sees stability as one of the key factors to consider in RPD design. Nor does the concept of indirect retention feature in the undergraduate's map. Such is the value of being able to interrogate the student's understanding simply by asking them to map the subject. Figure 5 presents another concept map constructed by a student who had been taught by the same teacher mentioned above. It can be seen that the conceptual overlap between the teacher map in Fig. 4 and the student map in Fig. 5, is significant. Although there are no direct links between Retention, Support and Stability, this student similarly sees these concepts as key in the development of a successful design. In this case the teacher can move forward with the teaching of RPD design in the knowledge that the theoretical underpinning is secure. On the other hand, an analysis of the undergraduate map in Fig. 4 (lower box) suggests that the teacher should revisit and reinforce certain aspects of theory. Being able to faithfully reproduce a linear presentation of RPD design does not demonstrate a deep understanding of the subject.

We suggest that expanding the shared arena between the teacher and the student (the dotted sections in Fig. 4) will allow the underlying networks of both the teacher and the student to be made public so that the teacher and the student can actively engage in the discourse of the discipline – both interrogating the underlying network of the other. Such a scenario can be observed to occur within the teaching clinic when the student

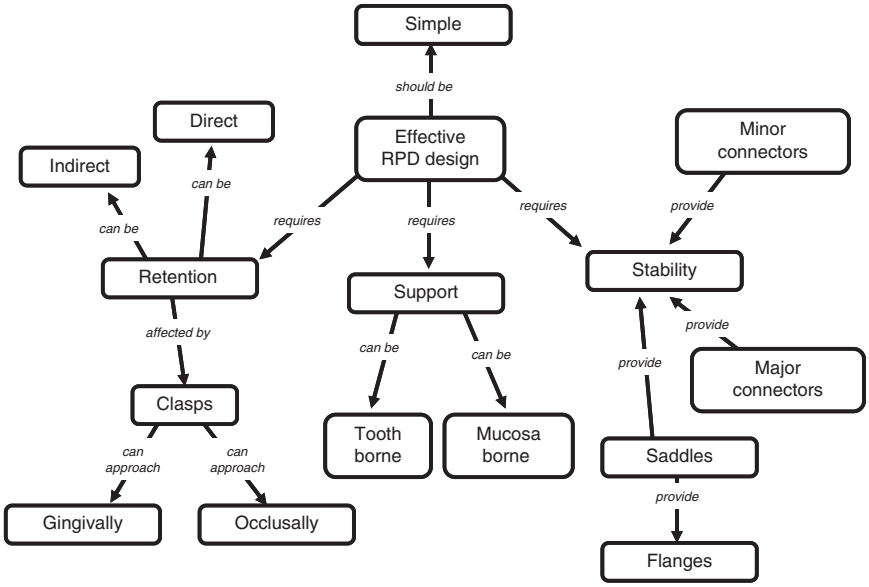

Fig. 5. Student map of removable partial denture design suggesting readiness for progression.

has sufficient courage to quiz the teacher. Such sharing of understanding is less often observed in the non-clinical teaching environment. The linking of clinical and non-clinical teaching through a common pedagogy is essential if students are to link the two successfully.

Concluding comments

The level of support needed to construct his/her own understanding of a subject such as RPD design will vary from student to student. However, it is clear that most need some support in creating a super-ordinate structure that will allow them to relate and link the elements of design. To do this before you have been taught the basics of design is an impossible task (it is having to know the answer so you can work out the answer). Therefore, an overall structure needs to be provided for the students so that they can concentrate on the details within a given context (Fig. 6). In the case of RPD design, presenting the undergraduate with the fundamentals of Support, Stability and Retention can give an overall structure within which the details of the design process can be arranged, but it is vital that the arrangement of such details is undertaken by the students themselves, as presenting students with a complete view of the topic will not encourage a deep learning approach.

Mapping in this manner will encourage and promote this approach to student learning; an approach that is only enhanced by the students now having an understanding as to why Lynch and Allen (21) and Frank et al. (22) differ as they do. Moreover, and just as important in the student learning experience, is the fact that interrogating student maps can

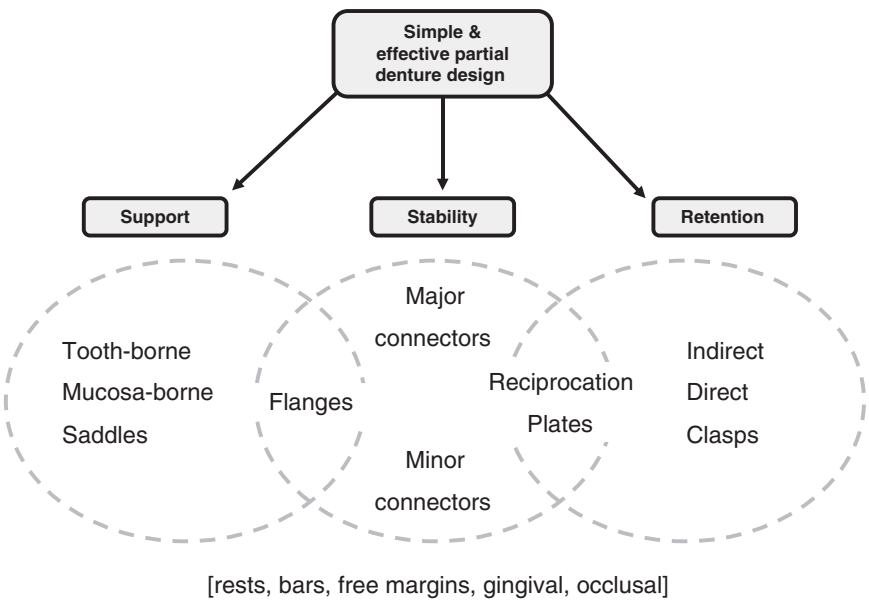

Fig. 6. An introductory structure that gives students the overarching framework (provided by Support, Stability and Retention) and indicates the areas where links may be most usefully formed with subordinate concepts.

provide the teacher with a priceless insight into a student's understanding of the subject. The teacher is therefore able to identify the student whose understanding is flawed and who needs guidance and or reinforcement of certain aspects of the subject. S/he is also able to see whose understanding is sound and is ready to move forward. We suggest that this is a priceless asset.

Just as our proposed teaching approach encourages the comparison of chains of practice with networks of understanding, so too does this article encourage the comparison of the linear text (analogous to the chain of exposition) with the more holistic depiction provided by the figures (analogous to the network of understanding). It reflects the structural transformation of information that students can undertake once they really understand.

Acknowledgements

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