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Concept-based teaching and learning: Integration and alignment across IB programmes

A report to the International Baccalaureate Organisation

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Executive Summary

Introduction

The notion of concept-based teaching and learning (CBTL) is not new. Originating in the work of Hilda Taba in the early 1960's, the fundamental assumption of CBTL is that in order to teach effectively, teachers needed to understand the three levels of knowledge: facts, basic ideas and principles.

Since the early 1960's, the CBTL approach has resonated and influenced research, curriculum design and teaching practices, as well as nurturing fundamental arguments for contemporary debates on the role of factual knowledge in curricula.

The IBO has been at the forefront of attempts to develop curricula to go beyond the transmission of facts. The research study reported here was commissioned by the IBO to assess how consistent the efforts to encourage concept-based teaching and learning have been.

RESEARCH METHODOLOGY

The major research questions of the current study were:

- What are effective approaches to CBTL, according to the state-of-the-art literature in the field?
- What are the existing approaches and understanding of CBTL embedded in relevant curriculum documentation in each IB programme?
- Are there developments in CBTL that are relevant to, but are not yet reflected in, IB programmes?

The first step was to undertake a **literature review** to identify effective approaches to CBTL and how conceptual understanding might be assessed in developmentally appropriate ways. The literature review used a rigorous search strategy, combined with both forward and backward snowballing. In total 158 items of research literature have been consulted, ranging from books to theses to chapters and journal articles, with the vast majority dated 2000 or later.

Secondly, the study aimed to closely examine the four IB programmes to determine the ways that such approaches were embedded in each set of guidelines and integrated across the programmes, based on a comprehensive **curriculum audit framework.** Based on the literature review, thirty-three principles were extracted. Using an inductive analysis, these principles were grouped into five themes: *The nature of concepts; Concept development; Concept-based teaching – key features; Classroom interaction in concept-based teaching; Assessing conceptual understanding.*

The principles were used as an audit tool to study the curriculum documentation for each of the four IB programmes. Based on the audit tool, a number of comparative analyses were carried out: generic comparisons between the four programmes and an analysis of several individual subjects across the four programmes. The subjects focused upon were Theatre Studies, Languages, Mathematics, Science, and History.

In order to understand the experiences and views of professionals involved in the management and design of the programmes, a set of **semi-structured interviews** were conducted with ten IB senior curriculum leaders.

RESEARCH RESULTS

Literature review

The literature review was structured around the four research questions which guided the selection, reading and synthesis of available material:

***Research question 1:* What are concepts and how do they typically develop in learners? How is this development influenced by teaching, maturation and/or experience?**

Although Piaget's (1952) theory of cognitive development is perhaps the most well-known and influential of all such theories in education, Piaget's view has been overtaken by a great many research findings into the process of conceptual development. Beyond Piaget's understanding of conceptual development, the literature review reveals new research evidence that needs to be considered by educators:

- **Young children are capable of abstract thinking** (Donaldson, 1986).
- Children's concepts are generally localised to a **particular area of expertise** and may not generalise to other areas without deliberate prompting. (Chi et al, 1981).Theories help learners to identify features relevant to a concept and influence how concepts are stored in memory. Therefore, even quite young children need to be encouraged to theorise (predict) about aspects of the world.
- The development of conceptual understanding appears to be **cumulative** (Chadwick, 2009), rather than in stages. As learners revisit concepts in various contexts as they learn, they gradually increase the breadth, depth, and complexity of their understanding.

One idea with some potential to explain some issues in conceptual development is that of "**threshold concepts".** Meyer and Land (2003) define a threshold concept as 'akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress.' (p.1). A threshold concept, thus, changes the way in which a student views a subject. Such a concept is likely to be challenging to the learner but, once acquired, is irreversible and transformative.

Research question 2: How can the development of concepts in educational settings and conceptual understanding in specific areas be assessed in ways appropriate to the particular learners?

Assessing students' understanding can be very challenging, both as a summation of their development over a fixed period and as a means of making individualised responses to meet their day to day learning needs. A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.

It has been suggested (Mucenski, 2004) that if the goal of a curriculum is to develop students' concepts about the world then a more appropriate form of assessment will be to ask students to use their reasoning skills to construct new conceptual structures based on their prior beliefs and newly learned information. Such assessments have been termed "authentic assessment", defined by Wiggins (1993) as "Engaging and worthy problems or questions of importance, in which students must use knowledge to fashion performances effectively and creatively".

One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback. Other relevant assessment tools suggested by the literature review are: *Semi-structured Interviews; Guiding questions; Open-ended essays; Think-Aloud Problem Solving; Graphic organisers; Concept maps; KWL charts; Word clouds.*

Research question 3: What models of CBTL have been proposed and how do these align with typical concept development?

In her seminal work of over 50 years ago, Taba (1962) emphasised the need to focus on conceptual understandings rather than the mere teaching of facts. This view is now echoed in the international literature on CBTL (e.g. Avery & Little, 2003; Erickson, 2002, 2007; Wiggins & McTighe, 2005). The key features of the concept-based instruction models discussed in the current study are given in the table below.

CBTL models – Key features

CBTL Model	Key references	Key features
Applebee curriculum integration model	Applebee (1996)	• Curriculum should not stress knowledge as a body of information to be mastered • Instead, knowledge is seen as action in a range of cultural practices, and traditions of discourse • Curricula are not catalogues of items, information, etc. • Rather, they exist to help students to integrate knowledge through extended conversations, and
5E Teaching model	Ampartzaki and Kalogiannakis (2015)	• Involves the use of modelling, demonstration, explanation and questioning, using 5 phases of activity, namely: – Engagement: Children encounter a topic and engage their preliminary understanding. – Exploration: Children search a variety of sources and use different ways to find answers or verify their initial ideas about the topic. – Explanation: Children develop evidence-based explanations about the topic. – Elaboration: Children try to apply their new knowledge to a different situation. – Evaluation: Children reflect on their learning and (in partnership with the teacher) assess their level of understanding.
Science-Technology - Science (STS) approach	Mbajiorgu & Ali (2003) Kapici et al (2017)	• Students try to solve problems relevant to their lives • They become involved in social issues and see science as a way of helping them become responsible citizens • They seek out information and use it in order to solve problems • They follow developments in technology and see the relation between scientific concepts and technological progression. • Teaching takes place not only in school but also in informal learning environments such as science centres and museums. • Students are encouraged to wonder about the future. • Students are encouraged to enjoy the science learning process.

Graphic organiser model	McCoy and Ketterlin-Geller (2004)	• The teacher determines the concept to be taught. • A graphic organizer is developed to show this concept and its links to other material. • Students' success in learning the concept is measured by seeing how they apply it across different contexts using more and more complex critical thinking.
Integrated Curriculum Model	VanTassel-Baska & Wood (2010)	Students are asked to: • identify examples of a concept, • organize and reflect upon it, • provide counter examples, • develop generalizations, • apply those generalizations to previous and future knowledge.
Understan ding by Design	Wiggins and McTighe (2005)	• Backward design - begins with the objectives of a unit and then proceeds "backwards" to create lessons to achieve those objectives. • The primary aim is student understanding: the ability to make meaning from "big ideas" and transfer learning to other contexts. • Understanding is demonstrated when students transfer their learning autonomously. • Teachers are coaches of understanding, not mere transmitters of content. • UbD reflects a "continuous improvement" approach. Student performance informs needed adjustments.
Erickson's model	Erickson (2012)	• Synergy – the interplay between the factual and conceptual levels. • "Just knowing the definitions of concepts is not sufficient. Just knowing facts is not sufficient". Learners need both. • Transfer of knowledge and skills –facts do not transfer as they are situated in particular contexts. Knowledge can only transfer at the conceptual level as generalizations and principles are applied across contexts. • Social construction of meaning – concept-based models function much more powerfully when collaborative group work is used to get different minds working together to generate new ideas.

Research question 4: What teaching approaches and strategies appear to facilitate the development of conceptual understanding?

The literature review extensively analysed the teaching approaches and strategies that can facilitate conceptual understanding. Among them, the *most relevant in being effective for conceptual understanding are:*

- the focus on the 'big ideas' (Sim, 2016);
- the learning cycle that involves teachers structuring their lessons to include inquiry-based teaching (Mucenski, 2004);
- the importance of classroom talk based on powerful questioning;
- macro and micro strategies for classroom interaction;
- active learning pedagogies, such as collaborative, cooperative, problem-based learning and self-directed learning.

Audit of programme documentation

Following the interrogation of a range of IB documents using the principles gleaned from the literature, a comparative table was drawn up, focusing upon a) how the principles were met, or not met, in the From Principles into Practice (FPiP) documents, and b) whether there were differences in the matching of these principles across the four IB programmes.

The visual summary of ways in which the four programmes currently meet the principles arising from the literature review were marked in the comparative tables, based on the following colour codes:

🟢	This principle fits with the material in the documentation
🟡	This principle partially fits with the material in the documentation
🔴	This principle does not fit with the material in the documentation
⚫	We could find no evidence regarding the fit of this principle

The nature of concepts in the IB programmes

A limited number of identified concepts are used to structure the content of the IB programmes. In PYP, MYP, DP and CP, these include both concepts identified as "big ideas", which are seen as trans- or interdisciplinary and also disciplinary concepts which set out the learning content of the programmes.

The terminology distinguishing "big idea" concepts which are "universal" and not confined to a subject is confusing. In PYP, Key Concepts are treated as both transdisciplinary and disciplinary. In MYP, Related Concepts are disciplinary and Key Concepts are interdisciplinary. Concepts at DP and CP are largely disciplinary, although they are also used to make links across subject areas.

The distinction made between Key Concepts and Related Concepts is not, as far as we could tell, derived from the literature, which instead claims that concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. The term 'concept' is used differently in Mathematics than elsewhere. Mathematical concepts are not seen as the overarching, categorising ideas that they are in other subjects.

There are significantly different structures both within subjects and across programmes and the conceptual nature of the curriculum is included in many of the structures - including ATL, key and related concepts, learning outcomes, phases and continua, assessment tasks and assessment criteria.

	Theme: The nature of concepts		PYP	MYP	DP	CP
Principles from the literature	1	Concepts are mental representations of categories of objects, events, or other entities.	🟢	🟢	🟢	🟡
	2	Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings", "essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.	🟢	🟢	🟢	🟡

	3	Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. It is important that some emphasis be given in teaching to the more over-arching concepts rather than trying to cover lots of material in a superficial way.	● green	● yellow	● yellow	● grey
	4	Concepts are tools for organising experience but also for extending the effects of such experience beyond the here and now.	● yellow	● yellow	● yellow	● grey
	5	A threshold concept changes the way in which a student views a subject. Such a concept is likely to be challenging to the learner but, once acquired, is irreversible and transformative.	● grey	● grey	● grey	● grey

The development of conceptual understanding

All the IB programmes showed a clear commitment to the development of conceptual understanding by students, in all subject areas. The expression of conceptual understanding becomes progressively more discipline-focussed as the student proceeds through the programmes. Curriculum leaders within IB see a concept-based approach to teaching and learning as a longer-term goal of the review process for programmes and subjects within the programmes and of an IB education generally.

	Theme: Concept development		PYP	MYP	DP	CP
Principles from the literature	6	Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts by deliberately introducing learners to a wider range of scientific/academic concepts that they probably would not develop simply through personal life experiences.	● green	● yellow	● yellow	● yellow
	7	Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.	● green	● green	● yellow	● grey
	8	Crucial to the development of scientific/ academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.	● yellow	● green	● green	● grey
	9	Young children are capable of abstract thinking, provided that the context of such thinking makes human sense to them.	● grey	● grey	● grey	● grey
	10	Theories help learners to identify those features that are relevant to a concept and influence how concepts are stored in memory. Therefore, even quite young children need to be encouraged to theorise (predict) about aspects of the world.	● grey	● grey	● grey	● grey
	11	Learners need to be encouraged to develop their concepts in an area through both assimilation (adding new information to existing mental structures) and accommodation (reworking existing conceptual structures to take account of new information).	● grey	● grey	● grey	● grey

	12	Students learn best when: a) concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general; b) concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned; c) the difficulty of a task meets student capabilities.				

Concept-based teaching
There are some gaps in the documentation we were able to access where it was difficult to find evidence that the principles derived from the literature did actually inform the IB approach. Looking at the nature of these gaps, it is clear that they mostly involve principles which focus upon actual classroom action (rather than underpinning curriculum structures).

This might suggest a gap in terms of the documentation, rather than practices. Perhaps there is a need for further documentation, and maybe CPD, to focus on pedagogy in order to help ensure that the sound theoretical underpinnings given in the programme guides might best be translated into effective classroom action.

		Theme: Concept-based teaching – key features	PYP	MYP	DP	CP
Principles from the literature	13	Effective concept-based teaching processes involve asking students to: a) identify examples of a concept, b) organize and reflect upon this, provide counter examples, c) develop generalizations, d) apply those generalizations to previous and future knowledge.				
	14	Concept-based teaching is conceived as a form of inductive teaching in which learners are guided to understand the big ideas rather than being taught directly about these ideas.				
	15	Curriculum should not stress knowledge as a body of information to be mastered, but rather as the joining in with traditions of discourse through which students are enculturated to the values of academic disciplines.				
	16	In concept-based teaching, teachers are not required to teach ALL the factual content of a subject but should select and reorganise only the material they need to ensure that their students can access and learn the big ideas.				
	17	The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects.				
	18	Approaches in which students are encouraged to apply their understandings to real life problems are more successful than traditional textbook-based approaches.				
	19	Backward design in curriculum planning begins with the objectives of a unit or course—what students are expected to learn and be able to do—and then proceeds “backwards” to create lessons to achieve those desired goals.				

	20	Key features of effective concept-based teaching models include recognising that both facts and concepts are essential elements of curriculum, and that learning is at its most effective when organised as a collaborative activity.	●	●	●	●
	21	Concept-based teaching can be thought of as a learning cycle divided into five steps: engagement, exploration, explanation, application, evaluation.	●	●	●	●
	22	The implementation of concept-based teaching can bring enhanced freedom to choose for teachers, but this can in itself generate lack of consensus, and teachers will need careful support as they try to implement such an approach.	●	●	●	●

Assessment approaches

The model of assessment presented in IB documentation at programme level offers numerous opportunities for concept-based assessment through both internal and external means. However, there are differences between programmes in how this is interpreted. Most IB programmes, even at MYP and DP levels, do include some element of more student-centred assessment. Such inclusions clearly support the inquiry-based philosophy which is so central to all IB programmes.

		Theme: Assessing conceptual understanding	PYP	MYP	DP	CP
Principles from the literature	27	Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.	●	●	●	●
	28	A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary	●	●	●	●
	29	Talking to learners, whether through structured interviews, guided questions, or encouraging thinking aloud is one of the most effective ways of accessing their thought processes..	●	●	●	●
	30	Asking students to express their ideas graphically can also provide a powerful window into their thought processes and understandings. This can involve the use of graphic organisers or concept maps	●	●	●	●
	31	Learners can be asked to represent their on-going understandings in more structured ways through devices such as KWL grids and word clouds.	●	●	●	●
	32	Teachers can detect changes in learners' conceptual understandings by looking for key indicators.	●	●	●	●
	33	One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.	●	●	●	●

IB senior curriculum managers perspectives on CBTL

Semi-structured interviews with ten senior IB curriculum leaders have revealed that all respondents recognised the importance of CBTL and identified conceptual understanding as the overwhelming goal of an IB education. Curriculum leads were all strongly committed to the idea of close alignment between CBTL and active learning pedagogies and authentic activities, actively promoting it through the guides and teacher support materials.

Colleagues discussing the role of concepts in the four programmes identified a confusion between concepts as “big ideas” which are “universal” and concepts as a form of learning beyond knowledge of facts. They related this to the growing disciplinarity of the programmes as students progressed through their schooling.

Interviewed senior staff also recognised that using a conceptual approach to curriculum content and planning could be challenging for teachers particularly for teachers at DP level, with their strong disciplinary backgrounds and experiences of other curricula.

CONCLUSIONS

The literature review undertaken in this study has confirmed that CBTL is a relevant approach for contemporary education that aims to promote the learning of concepts which facilitate the generation and understanding of ideas, the transfer of knowledge and skills, and a critical or reflective perspective towards knowledge itself.

A change in emphasis from factual to conceptual teaching does not necessarily mean a neglect of factual information but, instead, a change in the way this is used. Beyond Piaget's understanding of conceptual development, there are new research evidences that highlights the various features of cognitive understandings, as well as effective approaches fostering successfully students’ active and engaging learning. The IBO has already been recognised for consistently promoting some of the most effective teaching and learning approaches towards concept-based learning. New promising teaching and learning models related to CBTL may be further explored and promoted at the classroom level.

The curriculum audit undertaken under the current study clearly has shown that the IBO is committed to a consistent effort to encourage CBTL. Many of the principles arising from the literature review do appear to fit with IB curriculum documents. There are, however, some large gaps where it was difficult to find evidence that these principles informed the IB approach. Looking at the nature of these gaps, it is clear that they mostly involve principles which focus upon actual classroom action (rather than underpinning curriculum structures). This might suggest a gap in terms of the documentation, rather than recommended pedagogic practices. Perhaps there is a need for further documentation, and maybe Continuing Professional Development, to focus on pedagogy in order to help ensure that the sound theoretical underpinnings given in the programme guides might best be translated into effective classroom action.

RECOMMENDATIONS

Definitions

The term “concept”, and its subdivision into ‘key concepts’ and ‘related concepts’ is used freely in the documentation with some potential confusions. The origins of CBTL in the IB programmes is unclear and the ‘organic” development of ideas is one reason for the discontinuities in terminology, if not in principles. We recommend that the use of these terms be reviewed within the programmes, perhaps reserving the term ‘key’ for concepts which are truly of central importance to an area, and use the term ‘related’ for concepts which may be seen as of lesser importance.

Teacher development

Teachers are currently required, at PYP, to engage with transdisciplinary questions, key and related concepts, strands and phases. It would be worthwhile to establish whether further work to guide the asking of questions for inquiry, currently required through key concepts, could be presented for teacher use. It may be that IB teachers could be given more guidance in the use of direct instruction that meets these criteria, in the context of inquiry, so that they can achieve a flexible balance of direct and inquiry-led teaching.

Transferability and authenticity

Some consideration needs to be given to the idea of transferability (generalisability) within the IB programmes. We have raised some doubts about this and suggested the need for a closer look at concepts such as situated cognition and embodied cognition. A community of practice view of learning is already embedded, if not named, in the PYP model of teaching and learning and we suggest there is a lot of scope for integrating it into the MYP and DP. Considering a community of practice viewpoint as a basis for pedagogical organisation may also help clarify the issue of authenticity. This is easier to implement at PYP, where content is less tightly circumscribed. At MYP and DP, because of more tightly defined curriculum content, it gets harder to ensure that students perceive their curricula as authentic.

Future developments

Some further thought could be given to the nature of the learning process, taking into account the implications of schema theory. It will, we feel, be helpful in many ways for teachers to be explicit with their students about the ways in which learning works.

As we were unable to match several key principles arising from the literature review to programme documentation, we recommend that special attention may need to be given in future documentation and CPD to practical teaching strategies for teachers at all levels. Concepts such as dialogic teaching, and active learning need to be actively considered by teachers of IB programmes.

SOME LIMITATIONS

This project was not able to establish how teachers use the specifications for conceptual understanding only their role in the written curriculum. It would be interesting to know which structures and terminology teachers actually use in their planning, teaching and assessment of students at each programme level and we recommend some case studies in this area.

Introduction. Concept-Based Teaching: A New Educational Trend?

Concept-based teaching and learning (CBTL) has a respectable educational history. Hilda Taba's ideas in the early 1960's were responsible for changes in thinking about both subject content and the methods employed to teach it (Birbili, 2015).Taba's (1962) claim was that, in order for teachers to teach effectively, they needed to understand the three levels of knowledge: facts, basic ideas and principles, and concepts. If too much factual information was presented too quickly, students would find it difficult to make connections between the new information and the information stored in their minds. She maintained that, when facts were simply memorised and not connected to previously known information, students would forget the memorised facts very quickly. Since Taba's work, research has supported the importance of the teaching of conceptual rather than simply factual knowledge (Birbili, 2015).

This has not meant that the emphasis in schools on the teaching of facts has gone away. Memorisation still appears to be a key element in classroom teaching in many areas of the world, suggesting that facts and information are seen as more important than the way the human brain actually works.

Which does not mean to say that information and facts are redundant. Such a proposition has been strongly countered by the analyses of influential commentators such as Hirsch (1988) and Willingham (2009) who have argued that a knowledge base is crucial in the development of educated minds. Hirsch (1988), in fact, argued that there was a body of key knowledge whose mastery was crucial to a definition of 'educated' what Hirsch referred to as' cultural literacy'. The argument was that new knowledge depended for its understanding upon a network of previously acquired knowledge, the contents of which were shared with other members of a similar culture. (One area of debate about such a concept of cultural literacy is, of course, that essential knowledge would thus differ from culture to culture. The implications of this diversity for an international school system are problematic!)

For Erickson (2002), however, there were two main reasons why curriculum design needed to redress the balance between knowledge/facts, and concepts/generalisations.

a) The information explosion.

This can be evidenced in many ways but one historical trend has concerned the growth of published materials (McIlroy, 2009). For example:

- In the year 1450, 100 book titles were being published every year, equating to 0.2 titles per million inhabitants;
- By the year 1950, 250,000 book titles were being published per year -that is, 100 titles per million inhabitants;
- By the year 2000, 1 million book titles were published per year - 167 titles per million inhabitants.

What this means is that books are being published at such a rate that they actually make users more and more ignorant. If someone reads a book a day he/she would be neglecting 4000 other books published on the same days!

Erickson's interpretation of this information explosion was that teachers needed to make sure their students were equipped to deal with it, not through memorisation, which would be impossible, but through teaching them the skills to sort and integrate information. In other words, through the building of concepts, rather than the amassing of facts.

b) The changing purpose and nature of information

It can be argued that we live in such a fast-changing world that information itself is constantly being renewed and made redundant. It is clear that many of the 'facts' which we were all taught in school are now simply no longer true. One only has to consider the on-off planetary status of Pluto (Rice,2014) to get a sense that 'true' information is a time-situated concept.

So, perhaps facts are less useful today, especially in a world where we can always use Google to find things out? How can schools ensure that what their students learn is not redundant by the time they emerge from compulsory education? (Brown-Martin, 2015)

From Facts to Concepts

Oosterhof (2011) has argued that all knowledge exists at different levels of complexity and, in fact, the nature of highly complex declarative knowledge has been under-researched. Factual knowledge does have a place in learning but may not, in itself, create the ability in learners to apply knowledge to particular situations. It seems that the human mind deals not just in facts but also in bigger ideas – concepts. These two kinds of knowledge need to be linked if they are to be applicable in a range of situations. For example, you might eat Szechuan scallops at the Golden Heaven Restaurant. Knowing this is factual memory, referred to as 'episodic'. But knowing that Szechuan is a province in China, that its food tends to be spicy, and that scallops are shellfish are forms of conceptual knowledge. Episodic memory is specific to times, places, and individuals. Conceptual knowledge, rather, tends to be shared across individuals in a given culture, depending on an individual's experience, of course.

Research suggests, therefore, that learners need to build links across the information they encounter in their learning, developing and using what have been termed 'big ideas' to "make sense of lots of confusing experiences and seemingly isolated facts"(Wiggins,2010). It is not so much that facts no longer have a place in learning, but that they are used in a different way. The big ideas – concepts – help the learner make links between previous knowledge and understanding and extend, build and, perhaps, correct this in the light of new knowledge and understanding. The term often used to describe such ideas is schema (Rumelhart, 2013).

It seems logical to suggest that concepts and facts require different approaches to teaching (Birbili, 2015). Teaching may proceed via direct instruction, or via inquiry-led approaches. Researchers such as Kirschner et al (2006) have suggested that direct instruction is a superior approach in terms of student learning outcomes, although this conclusion is not universally accepted. Hmelo-Silver et al (2007), for example, argue that all learning involves knowledge construction in one form or another. The question of what kinds of teaching best support such knowledge construction, or learning, is crucial. It is possible that facts can be taught directly (if we define successful teaching simply as learners remembering the facts they have been taught), but the learners' construction of concepts is such an idiosyncratic process, it is hard to imagine how they might be passed on directly from one person to another. Concept-based learning requires new approaches to teaching. The existing research into approaches to concept-based teaching will be reviewed in the literature review which forms a major part of our project.

Research aims and questions

The aims of this study were, firstly, to undertake a literature review to identify effective approaches to CBTL and how conceptual understanding might be assessed in developmentally appropriate ways. We took this to imply that a review would mainly focus on evidence-supported approaches to the implementation of CBTL in a range of settings. In order to achieve this aim, we also needed, however, to review what was currently known about how learners develop concepts and how such development might best be assessed.

The second research aim was to carry out a close examination of the four specified IB programmes to determine the ways that such approaches were embedded in each set of guidelines and integrated across the programmes.

Research questions for this study included the following:

1. What are effective approaches to CBTL?
    a. What are existing models of CBTL?
    b. What teaching approaches and strategies are associated with CBTL and/or effectively facilitate the development of conceptual understanding?
    c. How does conceptual understanding develop (cognitively) over time in learners?
    d. How can conceptual understanding be assessed in developmentally appropriate ways?
2. What are the existing approaches and understanding of CBTL embedded in relevant curriculum documentation in each IB programme?
    a. How does each IB programme develop conceptual understanding?
    b. To what extent does the role and integration of concepts align within and across the IB programmes?
    c. How do IB approaches to CBTL compare with best practices and contemporary developments in the field?
    d. In what ways could the IB better align CBTL within and across the programmes?
3. Are there developments in CBTL that are relevant to, but are not yet reflected in, IB programmes.

Methods of inquiry

Developing a literature review

The first aim of this study was to undertake as systematic a literature review as possible to identify effective approaches to CBTL and how conceptual understanding can be assessed in developmentally appropriate ways.

Our first step, therefore, was to develop a range of linked search terms, including "concepts", "concept development", "concept-based teaching", "concept-based learning", "assessment of concept development". These terms were used for our initial literature searches, using the search strategy elements outlined below, although we remained open throughout to the development of other relevant search terms, in response to our reading of the literature we uncovered.

In searching for material to potentially include in the literature review, we tried to prioritise research-based articles, published in high status journals, all the while recognising, naturally, that material might emerge which was useful but did not meet that particular criterion. Where necessary, therefore, we included in the search research-based material published in less highly-rated journals, book chapters, books and, very occasionally, where the material seemed highly significant, 'grey' literature such as blogs, websites, unpublished papers etc.

Our search and review strategies were guided by the research questions underpinning the project. Thus, our literature review was structured into four main headings:

1. What are concepts and how do they typically develop in learners? How is this development influenced by teaching, maturation and/or experience?
2. How can the development of concepts in educational settings and conceptual understanding in specific areas be assessed in ways appropriate to the particular learners?
3. What models of CBTL have been proposed and how do these align with typical concept development?
4. What teaching approaches and strategies appear to facilitate the development of conceptual understanding?

The overall aim of this literature review process was to produce a set of research-based principles for and features of effective concept-based teaching, which could then be used as a template for subsequent auditing of curriculum documents.

Steps in the method

The research method for the literature review presented here was based on the guidelines given by Kitchenham and Charters (2007) and Petersen et al. (2015). It involved three main phases:

1. Planning: this refers to the pre-review activities, which aimed to establish a review protocol beginning with the research questions, and going on to define inclusion and exclusion criteria, sources of literature, and the search string.
2. Conducting: in this phase the initial searches were conducted and relevant studies selected. An on-going record was kept of themes emerging, and the

ways in which studies reviewed related to one another. All studies reviewed were initially classified according to which of the research questions they particularly related to (many related to more than one), and a thematic map was gradually built up.

3. Reporting: this final phase involved the production of a written review suitable for external consumption. In the case of the present project, this review was substantially reshaped after an initial draft, and it needed to be produced in a form suitable for subsequent use as an audit tool for extant curricula.

Inevitably, the process of locating literature relevant to the research questions was not quite as simple as the above phase description suggests. We did at several points also find it necessary to conduct forward and backward snowballing activities using the reference lists and citation records of selected studies, in order to identify additional relevant studies (Wohlin, 2014). Some manual searches for works developed by important researchers and research groups were also performed. These researchers/research groups were identified from previously selected studies (retrieved by searches in the databases, as well as from snowballing). We used these two approaches in our search to overcome the limitation of using a specific set of electronic databases.

Refining a search string

Secondary studies, such as that we engaged in as the first step in this research project, are based on analysing the research papers (primary studies) in an area. Their aim is to provide an overview of a topic area, to draw conclusions and implications from existing research and to identify whether there are subtopics where more primary studies are needed (Glass, 1976). In order to accomplish this, we first needed to locate such research papers, and a crucial step in this was to develop a search string which could be applied to the range of relevant, existing databases of published research papers. Our approach to this was to use a version of brainstorming, using material in the Request for Proposals, to highlight a list of potential search terms. These initially consisted of the following: "concepts", "concept development", "concept-based teaching", "concept-based learning", "assessment of concept development". The databases we had available all allow for Advanced Search techniques (although in Google Scholar, this is achieved in a slightly different way to in the more academic databases). We thus were able to combine our initial search terms, using the Boolean term OR. The search string presented below was used to search a range of electronic databases.

Initial Search String: "concepts" OR "concept development" OR "concept-based teaching" OR "concept-based learning" OR "assessment of concept development" OR "concept learning".

The aim of the initial literature search was to be as comprehensive as possible in terms of the material we located. As a means of testing the efficacy of our developed string, we established a list of 10 papers which we already knew of from the development of our research proposal. Our reasoning was that, if our search string was sufficiently rigorous and comprehensive, it ought, when applied, to turn up at the least all the items on our initial list. In this sense, the initial list was used as a control to calibrate the search string. In the event, all

10 of our pre-selected sources were produced early on in our searching procedure, so we felt reasonably confident that we had a workable and productive search tool.

Sources

In terms of sources for the review, we had ready access to three main meta-databases (which included access to a range of other databases, as listed below). These were:

- The University of Nottingham Library search system – *NUSearch*.
- The University of Warwick Library search system – *Encore*.
- Google Scholar

These three meta-search systems do overlap to a degree in the databases which they interrogate, but not 100%. Using all three was thus likely to produce a more comprehensive outcome than would using only one system. The two University search systems tend to favour material published in peer-reviewed outlets, whereas Google Scholar also includes material made public on personal, commercial and university web servers, which may not have been through such a rigorous pre-selection.

Testing the search string

The initial search string was tested using the University of Nottingham *NuSearch* system. The initial return produced over 1.7 million hits! Clearly more filtering was needed.

The search engine provided several potential filters. The following were selected:

- Full text available online AND
- Dates from 2000-2018 AND either of:
- Peer reviewed journals
- Articles
- Conference proceedings
- Dissertations
- Theses

It was noticed that a large number of these hits referred to material from nursing education. Although interesting theoretically, most of this material was not of direct relevance to the present topic and consequently the search string was altered to include NOT nursing and NOT medical. The application of these filters had the effect of narrowing the hits to 1821 papers, a much more manageable number. (It should be noted, however, that a small number of papers focusing on nursing or medical education WERE, in the end, referred to in the literature review, as they emerged though the process of snowballing.)

The next step was to manually inspect each returned item, taking account of title and, in cases of doubt, abstract to determine relevance to the topic. Naturally, the issue at this point concerned the possible introduction of an element of subjectivity into the selection. To mitigate this, a sampling exercise was carried out using the first 100 returned items. These were examined by 2 members of the research team who each, separately, selected/excluded papers according to a number of criteria. These criteria were:

- Did the paper focus upon, or have clear relevance to, the schooling of 3 to 18-year-old students?
- Was the main focus of the paper either concept development in learners, CBTL and/or teaching/assessment strategies relating to these?
- Did the paper either report original research, or use extant research findings to develop its argument?
- Had the paper been peer-reviewed?

The emerging exclusion lists from this exercise were compared. 100% of the deletions were found to match between the two judges, which persuaded us that our selection criteria in this exercise were robust and replicable. One researcher then went through the entire list of 1821 hits, examining titles and abstracts and deleting those papers that did not the inclusion criteria listed above. A large number of items were deleted from the list by this means. In fact, we found that the majority of the returned items did not meet our criteria of usefulness and were thus discarded. Examples of items discarded were articles dealing exclusively with higher education contexts, and with the conceptual structure of particular subjects (as distinct from the teaching and/or learning of this conceptual structure). The final list of papers that would influence our literature review was thus 95 from this search source.

A similar process was used to check for possible material using the University of Warwick *Encore* search system. This works in a slightly different way to the Nottingham system but the basic principles are the same. Because of variations in the precise databases used and the ways in which the filter terms operated, the list of suitable papers returned from the Warwick search was 1696. The majority of these (1683) were, inevitably, duplicates of material already obtained through our searching. Of the remaining 13 papers, 5 passed through our manual relevance checking process, thus producing a total list of 100 items to contribute to our review.

Google Scholar proved the least productive of the search systems we used, its Advanced Search system being much clumsier and harder to fine tune than that of the two library systems. Google Scholar also produced many hits that were either citations or undownloadable books. In the event, only one unique publication was located using Scholar.

Our search thus produced 101 papers/books etc. that contributed to our literature review. It should be noted that this collection was of material which we could actually get hold of through our Library systems and/or the Internet. The collection was thus biased against published books, most of which were not obtainable without purchasing them. This was not considered to be an important flaw in the process, given the deliberate choice we had made to prefer research material.

Initial categorisation

The publications were firstly categorised by date of publication. Figure 1 shows a graphical representation of these dates. It can be seen that there has been a significant increase in the number of publications on this topic since 2014, an indicator of rising interest, suggesting that this was an opportune time to review this literature.

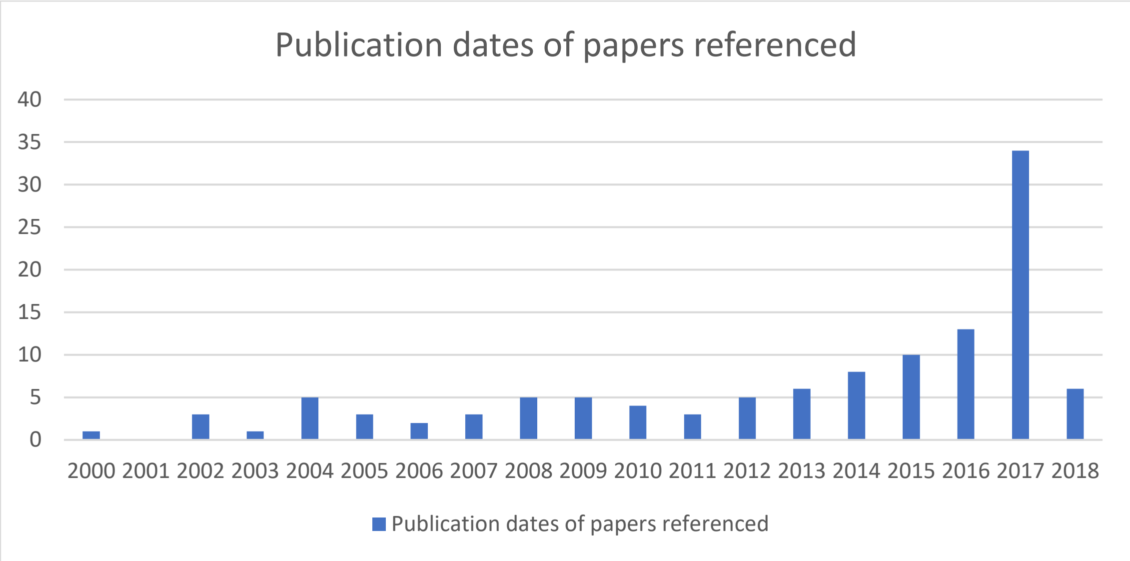


Figure 1: Dates of publication of initially selected publications

The publications were also categorised by type, namely whether their major orientation was to report original research, to comment upon and analyse research in theoretical terms, or to offer practical advice to schools and teachers. Figure 2 shows this breakdown and demonstrates the preference in our literature review for material either reporting original research or commenting upon it theoretically.

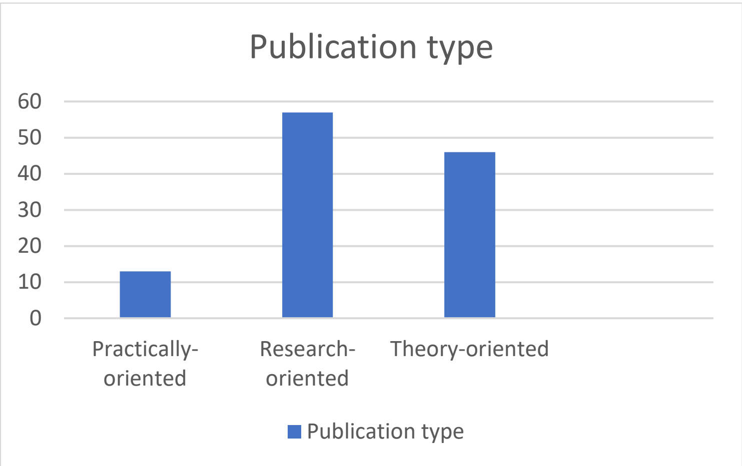


Figure 2: Types of publications reviewed

The papers were then categorised in terms of the main theme they addressed, defined according to the Research Questions of the study. These were:

1. What are concepts and how do they typically develop in learners? How is this development influenced by teaching, maturation and/or experience?
2. How can the development of concepts in educational settings and conceptual understanding in specific areas be assessed in ways appropriate to the particular learners?
3. What models of CBTL have been proposed and how do these align with typical concept development?
4. What teaching approaches and strategies appear to facilitate the development of conceptual understanding?

Each paper was skim read, paying particular attention to its abstract and conclusion, and then assigned to whichever of these research questions and sub-questions that it best fitted. With many of the papers, this was relatively unproblematic but with a large number, it was felt that the paper addressed more than one of the research questions. Such papers were double, or in some cases triple, categorised.

We were, at this point, ready for a detailed reading of the papers in our collection, taking each main theme in turn and firstly attempting a summary of each publication's themes and outcomes. It was at this point also that any necessary forwards and backwards snowballing was carried out, using either the reference lists of a published work (backwards snowballing) or checking the work in a citation index (forward snowballing). Our aim was to produce the most up to date review that we could, so we were cautious in our use of backwards snowballing not to include too many publications which had appeared prior to the year 2000 (which we had set as the cut-off date in our earlier searching activity).

An annotated bibliography containing summaries of the majority of the sources which were used in producing this literature review can be found in Appendix 3 (Page 149) of this report. The exceptions in the bibliography occur when a paper did not make much of a contribution to the overall argument of the literature review. There are 78 entries in the annotated bibliography.

Auditing IB programmes and materials

The process of auditing the four IB programmes began while the literature review was underway and involved the selection and curation of IB programme documents with a focus on the documents which inform IB teachers' practices at each programme level.

The key concepts for analysis were derived from features of successful practice identified in the review of literature (see the literature review below). A list of key principles was extrapolated from this review, and used to build as coherent a conceptual framework as possible in order to enable comparisons with and between IB programmes and subjects. These principles and the framework arising will be presented following the literature review below.

A set of IB documents representing the four programmes: PYP; MYP; DP; and CP were selected and curated. These included the key programme documents in the selected areas, additional guidance for parts of the programmes such as Extended Essay, TOK, CAS and assessment guidance for each programme level. Members of the subject team then carried out a detailed reading and critical review of the IB documents to identify the concept teaching and learning opportunities, the opportunities for features of successful practice presented by these documents and the assessment opportunities, using the key principles and conceptual framework, transformed into a series of focus questions, as comparators.

On-going findings and ideas were discussed at several team workshop meetings, before the writing of the final report analysis.

Interviews with IB personnel

In order to understand the experiences and views of professionals involved in the management and design of the programmes we conducted semi-structured interviews with ten senior leaders, including:

- Five Heads of Programme Development
- Four Senior Curriculum Strand Managers selected across programmes and areas in cooperation to reflect the selections made in the documentation included in the audit.
- The Head of curriculum innovation and alignment lead

The interviews aimed to understand:

- The existing approaches and understanding of CBTL embedded in relevant curriculum documentation.
- How each IB programme develops conceptual understanding.
- Alignment and integration of concepts within and across the IB programmes.
- Aspects of curriculum particularly where CBTL is seen as successful in classes.
- Aspects of the planned curriculum presenting challenges to teachers and students.
- Identified discontinuities identified in curriculum documentation.

Interviews were conducted electronically and lasted around 45 minutes and were transcribed and analysed using Nvivo 12 to gain insights into the challenges faced in managing the complex interplay of concepts and assessments. This key goal was to understand how the planned curriculum works in practice and the possible contrasts between the envisaged and enacted curriculum.

Outcome 1: The Literature Review

The literature review is structured around the four research questions which guided our selection, reading and synthesis of available material. These are repeated here to refresh the reader’s mind.

1. What are concepts and how do they typically develop in learners? How is this development influenced by teaching, maturation and/or experience?
2. How can the development of concepts in educational settings and conceptual understanding in specific areas be assessed in ways appropriate to the particular learners?
3. What models of CBTL have been proposed and how do these align with typical concept development?
4. What teaching approaches and strategies appear to facilitate the development of conceptual understanding?

For each research question, the aim in reviewing relevant research was twofold. Firstly, we needed to gain a critical understanding of the key ideas and developments relating to each research question. And, secondly, we needed to extract principles or sets of principles related to each area which could then be used as part of an auditing tool to assess IB programmes and subjects. In what follows, we present the outcomes of the literature review focused on each research question, interspersing this with highlighted principles as they emerged.

Research question 1: What are concepts and how do they typically develop in learners? How is this development influenced by teaching, maturation and/or experience?

The nature of concepts

Within the context of human knowledge in general, Binwal and Lalhmachhuana (2001) have defined "knowledge representation as a systematic way of codifying human knowledge" and affirm that any knowledge representation system depends upon the existence of a structured way of representing aspects of the world. They further argue that a central part of such representation consists of elaborating: (1) a set of concepts about the world; and (2) the relationships between these. Gärdenfors (2000) concurs in suggesting that the central question for any theory of knowledge representation is how concepts are modelled and structured. It seems central to any understanding of how we, as human beings, know about the world that we consider the nature of concepts, how they are structured and how they might be expanded and strengthened. We also, as educators, need an understanding of how we might through education ensure such knowledge in younger human beings (Smith & Zeng, 2004). CBTL depends upon an agreed notion of what constitutes a concept.

Concepts are mental representations of categories of objects, events, or other entities (Jonassen, 2006). We recognize and communicate thousands of concepts every day, mostly without any conscious attention to learning them. Concepts are the basis for meaning making and communication. It is almost impossible to imagine trying to communicate without using concepts. Even a simple activity like describing my cocker spaniel to another person would, in the absence of the short cuts afforded by concepts such as 'dog', 'animal', 'friend', etc, be impossibly complex. I would have to describe every characteristic of this four-legged, furry, merry creature, and even then, unless my listener has seen this very animal and matches it to my description, the process would be very 'hit-and-miss'. I could not simply call it a cocker spaniel because that in itself is a concept. I would have to link my description to that of many other similar creatures, pointing out the similarities and differences between my example and other possible examples. Communicating without concepts is impossible. (Jonassen, 2006)

> ***Principle:***
> Concepts are mental representations of categories of objects, events, or other entities.

The concepts referred to in the previous paragraph would generally be referred to as spontaneous concepts, a term arising from the work of Vygotsky (1978). Vygotsky's claim is that children naturally construct spontaneous concepts in reference to the objects they encounter in their everyday lives. Spontaneous concepts are based on their personal experiences with and their perceptions of these objects. For example, a young child may be able to say who their sister is, but they cannot explain the concept of siblings or, indeed, the word "sister" (Lai, 2012). Their knowledge is limited to the person they see every day and to the world which immediately surrounds them. Such spontaneous concepts are built up in a bottom-up manner, based on limited experiences and observations. They do not provide a deep or systematic account of any given subject matter. By contrast, other concepts are built up in a top-down manner, with children first encountering the verbal definition of the concept in the context of educative experiences, at home or at school. The definition is then exemplified by experiences with individual objects that fall into this conceptual category (Vygotsky, 1978). Conscious awareness and voluntary control appear to be two of the main features associated with the acquisition of such scientific concepts (Bakhurst, 2007). Organised teaching, designed to fulfil specific purposes, arouses children's conscious awareness of a concept. They are then given opportunities to practice and extend what they have learnt until they are in control of the concept at issue. It has been argued (Smagorinsky et al, 2003) that a better translation for "scientific concept" would be academic concept. Regardless of the translation, the key distinguishing factor is that scientific/academic concepts are generalizable across situations, while spontaneous concepts are ways of categorising particular experiences.

> ***Principle:***
> Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts by deliberately introducing learners to a wider range of scientific/academic concepts that they probably would not develop simply through personal life experiences.

> ***Principle:***
> Crucial to the development of scientific/academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.

Ogena (2004) has referred to this change as the 'Intellectual-Competency View of Adolescence' and outlines that the changes that occur during adolescence are changes in abstract thinking abilities, peer relations and friendships that help individuals explore their similarities and differences, and moral thinking (their views about right and wrong). Unlike younger children, adolescents are capable of abstract thinking, and begin to understand the thought processes of others and interact with the environment in new and different ways. Cognitive development reaches its peak at this time. Piaget (1952) argued that intelligence developed in a series of stages reflecting biological maturation as well as cultural influences. While a pre-adolescent may already be capable of concrete operational thinking, i.e., thinking about what is "here and now", an adolescent can go beyond this to think about what might be, not just what is. Abstract thinking permits consideration of questions such as "who am I?" and answer this question in ways beyond just age, name and various likes and dislikes. The adolescent also has the thinking skills to judge between alternatives and to make longer term plans and commitments.

It seems, then, that from an early age humans build theories to explain their world (Jonassen, 2006). Through experience, reflection and deliberate teaching, humans add and develop concepts as they learn. We add to and restructure concepts only if they are comprehensible and coherent with our existing conceptualizations and theories. The cognitive process of adapting and restructuring these theories is conceptual change (Vosniadou, 1999). This model of conceptual change is Piagetian, whereby learners gradually restructure their existing knowledge in the light of new learning. Sometimes new concepts can be assimilated into existing cognitive structures, but sometimes the new information might give rise to a more radical restructuring, or accommodation, as children attempt to synthesize what they are learning with their existing naive mental models (Vosniadou & Brewer, 1992).

Principle:
Learners need to be encouraged to develop their concepts in an area through both *assimilation* (adding new information to existing mental structures) and *accommodation* (reworking existing conceptual structures to take account of new information).

Conceptual development

Piaget's (1952) theory of cognitive development is perhaps the most well-known and influential of all such theories. It emerged from extensive observation of children, including his own, in their natural environments rather than in laboratories. Piaget was interested in how children reacted to their environments, but suggested a more active role for them than that suggested by the then current learning theory. He saw a child's knowledge as composed of schemas, basic units of knowledge used to organize past experiences and to serve as a basis for understanding new ones. Schemas are continually being changed by two processes that Piaget called assimilation and accommodation. Assimilation is the process of learning new information by building it into an existing schema. In other words, learners assimilate new experiences by relating them to things they already know. Alternatively, accommodation is what happens when the schema itself changes to incorporate new knowledge. Piaget suggested that cognitive development involves a continuous attempt to balance assimilation and accommodation and referred to this as equilibration. At the centre of Piaget's theory is the principle that cognitive development occurs in a series of four distinct, universal stages, each characterized by increasingly sophisticated and abstract levels of thought. These stages always occur in the same order, and each builds on what was learned in the previous stage. The stages are: (Huitt and Hummel, 2003)

- Sensorimotor stage (infancy): In this period, intelligence is demonstrated through motor activity without the use of symbols. Knowledge of the world is limited, but developing, because it is based on physical interactions and experiences. Children acquire object permanence at about seven months of age (memory). Physical development (mobility) allows the child to begin developing new intellectual abilities. Some symbolic (language) abilities are developed at the end of this stage.
- Pre-operational stage (toddlerhood and early childhood): In this period, intelligence is demonstrated through the use of symbols, language use matures, and memory and imagination are developed, but thinking is done in a non-logical, non-reversible manner. Egocentric thinking predominates.
- Concrete operational stage (elementary and early adolescence): In this stage, intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking develops (mental actions that are reversible). Egocentric thought diminishes.
- Formal operational stage (adolescence and adulthood): In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts. Not every adult will operate in this stage, at least not all the time.

Younger school-age children, 6 to 12 years old, tend to be at the "concrete operations" stage of Piaget's cognitive development model, characterized by the ability to use logical and coherent actions in thinking and solving problems. They understand the concepts of permanence and conservation by learning that volume, weight, and numbers may remain constant despite changes in outward appearance. These children should be able to build on past experiences, using them to explain why some things happen. Their attention span should increase with age, from being able to focus on a task for about 15 minutes at age six to an hour by age nine.

Adolescents, aged from 12 to 18, will be moving into the "formal operations" stage, with an increased independence in thinking through problems and situations. Adolescents should be able to understand abstractions, and learn and apply general information to specific situations. They should also be able to learn specific information and skills. A major component of the passage through adolescence is a cognitive transition. Compared to younger children, adolescents think in ways that are more advanced, more efficient, and generally more complex. This ability can be seen in five ways. Firstly, during adolescence, individuals become better able than children to think about what is possible, instead of limiting their thought to what is real. Whereas children's thinking is oriented to the here and now—that is, to things and events that they can observe directly— adolescents are able to consider what they observe against a backdrop of what is possible; they can think hypothetically. Secondly, during the passage into adolescence, individuals become better able to think about abstract ideas. For example, adolescents find it easier than children to comprehend the sorts of higher-order, abstract logic inherent in puns, proverbs, metaphors, and analogies. The adolescent's greater facility with abstract thinking also permits the application of advanced reasoning and logical processes to social and ideological matters. This is clearly seen in the adolescent's increased facility and interest in thinking about interpersonal relationships, politics, philosophy, religion, and morality. Thirdly, during adolescence individuals begin thinking more often about the process of thinking itself, or metacognition. As a result, adolescents may display increased introspection and self-consciousness. Although improvements in metacognitive abilities provide important intellectual advantages, one potentially negative by product is the tendency for adolescents to develop a sort of egocentrism, or intense preoccupation with the self. A fourth change in cognition is that thinking tends to become multidimensional, rather than limited to a single issue. Whereas younger children tend to think about things one aspect at a time, adolescents can see things through more complicated lenses. Adolescents describe themselves and others in more differentiated and complicated terms and find it easier to look at problems from multiple perspectives. Being able to understand that people's personalities are not one-sided or that social situations can have different interpretations depending on one's point of view permits the adolescent to have far more sophisticated and complicated relationships with other people. Finally, adolescents are more likely than younger children to see things as relative, rather than absolute. From seeing things in absolute terms—in black and white—adolescents begin to be able to see things as relative. They are more likely to question others' assertions and less likely to accept facts as absolute truths.

The above description of the Piagetian theory of conceptual development has been immensely influential, having virtually founded the constructivist model of learning. It would today, however, be perceived as relatively naïve and has been overtaken by a great many research findings into the process of conceptual development. Some of these are summarised by Gelman (1999), who puts forward four key themes which have emerged from research into concept development in young children.

- Theme 1. Concepts are tools and provide an efficient way of organizing experience. They therefore have powerful implications for children’s reasoning—both positive and negative. However, concepts do more than organize information efficiently in memory. They also serve an important function for a range of cognitive tasks, including identifying objects in the world, forming analogies, making inferences that extend knowledge beyond what is already known, and conveying core elements of a theory. Many of these tasks are central to school performance; thus, concepts can be thought of as the building blocks to these more complex skills.

Principle:
Concepts are tools for organising experience but also for extending the effects of such experience beyond the here and now.

- Theme 2. Children’s early concepts are not necessarily concrete or perceptually based. Even pre-school children are capable of reasoning about non-obvious, subtle, and abstract concepts. In many older accounts, concepts, it is claimed, undergo a fundamental, qualitative shift as children develop. Children and adults are often said to be at opposite points of various dichotomies, from perceptual to conceptual or from concrete to abstract. However, as a description of what children are *capable* of doing, such dichotomies are inadequate. With appropriately sensitive tasks, children can display abilities that may not appear in their everyday actions, and may surpass what the development models claim they can do (Donaldson, 1986).

> ***Principle***:
> Young children are capable of abstract thinking, provided that the context of such thinking makes human sense to them.

- Theme 3. Children's concepts are not uniform across subject areas, across individuals, or across tasks. Specialist knowledge can exert surprisingly powerful effects. Chase and Simon (1973), for example, found that chess experts have superior memory for the position of pieces on a chessboard, although they are no better than non-experts in their general memory. Chi (1978) demonstrated the same phenomenon in children. Child chess experts could even outperform adult chess novices! In these examples, experts did not seem in general to be more intelligent or more skilled than novices. The effects appeared to be localized within the domain of expertise. In concept development, children's level of sophistication varies a great deal by content area. Chi et al (1981) found that expert problem-solvers and novice problem-solvers approached word problems about physics quite differently, focusing on altogether different features of the task.

> ***Principle***:
> Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.

- Theme 4. Children's concepts reflect their emerging "theories" about the world. To the extent that children's theories are inaccurate, their conceptions are also faulty. A central developmental question is when and how children begin to incorporate theories into their concepts. One long-held view was that children's initial categories are similarity-based and that children only begin to incorporate theories as they gain experience as a result of formal schooling (Quine 1977). It was also argued by Piaget that pre-operational children do not have the logical capacity to construct either theories or true concepts. In contrast to such views, many researchers now believe that concept acquisition in childhood may require theories. Murphy (2002) notes that theories help concept learners to identify those features that are relevant to a concept and they influence how concepts are stored in memory. The implication is that concept acquisition proceeds more smoothly with the help of theories. Conversely, errors in children's theories may also constrain children's concepts. Gelman and Williams (1997) found that primary school children's understanding of arithmetic was heavily influenced by the theory that numbers are countable items, starting with one and continuing by adding whole numbers. Based on this assumption, children experience great difficulty when first meeting fractions, often treating them as if they were whole numbers (Gelman and Williams 1997). For example, when asked to sort cards (representing different amounts) onto a number line, children would treat a card with 1½ on it as if it represented "2" on the number line. The difficulty the children had was not simply that they were meeting a new set of mathematical operations but that their prior theory clashed with the new system. Similar theory-driven errors have been found in young children's reasoning about physics (Kaiser et al. 1986) and biology (Coley 1993).

Principle:
Theories help learners to identify those features that are relevant to a concept and influence how concepts are stored in memory. Therefore, even quite young children need to be encouraged to theorise (predict) about aspects of the world.

The development of conceptual understanding appears to be cumulative (Chadwick, 2009). As learners revisit concepts in different contexts throughout their learning, they gradually increase the breadth, depth, and complexity of their understanding.

Principle:
Teachers can detect changes in learners' conceptual understandings by looking for key indicators, namely when:

- the level of their understanding and use of abstract concepts increases;
- they make connections between multiple concepts;
- they apply and transfer their understandings to more complex and distant contexts as well as to those that are familiar;
- they take responsible actions and make informed decisions that are based on their new understandings;
- they begin to understand that concepts can have different interpretations.

Threshold concepts

One notion with potential to explain some issues in conceptual development is that of "threshold concepts". Earlier in this report, we described the inclusion/exclusion filters we used to select material to form part of this literature review. One of these was that included papers should "focus upon, or have clear relevance to, the schooling of 3 to 18-year-old students". Papers on the topic of threshold concepts were initially excluded from our review on the grounds that they did not meet this inclusion criterion. Threshold concepts have been the subject of a burgeoning area of educational research over the last ten years, but the original research from which the notion was developed (Meyer & Land, 2003), and the vast majority of the research and commentary which has appeared since, has been focused on undergraduate and professional education. A comprehensive account of threshold concepts and the literature the notion has generated can be found on the website maintained by Flanagan (2019). The topic did emerge in the forward snowballing carried out as part of the compilation of this review, but very few attempts have been made to apply this notion at school level – and we could find no research studies at all. But there are some recent indications that this may be changing. Kaiser (2018), for example, has suggested some applications in the teaching of secondary science, and Enser (2018) suggests some implications for secondary geography teaching. It may be, therefore, that the notion has some potential in thinking about the development of CBTL at school level and it is for this reason that we mention it fairly briefly here.

What exactly are threshold concepts and how can they be used to inform teaching? According to Meyer and Land (2003), a threshold concept 'can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress.' (p.1)

On this basis, then, they might be considered as the crucial elements of disciplinary understanding – the things that make some students 'get it' while others do not. A threshold concept is often described as a concept or perspective that causes the learner to 'see things in a new way' (Meyer & Land, 2003, p. 1), thereby acting as an entry point to a new subject. An extensive body of research, drawn from their work, suggests that, once understood, threshold concepts offer an insider perspective of a particular subject.

A threshold concept has a number of key features:

- It is transformative: Once understood, a threshold concept changes the way in which the student views the discipline. On mastering a threshold concept, the learner begins to think like a professional in that discipline and not simply like a student of that discipline.
- It is troublesome: Threshold concepts are likely to be troublesome for the student. Perkins (2006) has suggested that knowledge can be troublesome when it is counter-intuitive, simply because the learner does not wish to change or let go of their customary way of seeing things.
- It is irreversible: Given their transformative potential, threshold concepts are also likely to be irreversible, that is, they are difficult to unlearn. This is supported by the difficulty that some teachers find in recognizing threshold concepts that students may encounter in their courses. "One of the difficulties teachers have is that of retracing the journey back to their own days of 'innocence', when understandings of threshold concepts escaped them in the early stages of their own learning." (Cousin, 2006, p.4)
- It is integrative: Threshold concepts, once learned, are likely to bring together different aspects of the subject that previously did not appear, to the student, to be related.

Principle: A threshold concept changes the way in which a student views a subject. Such a concept is likely to be challenging to the learner but, once acquired, is irreversible and transformative.

Concepts and concept teaching

Concepts were earlier defined as mental representations of categories of objects, events, or other entities. They have also been defined as abstractions of events, objects, or phenomena, with emphasis upon their abstract quality (Agbo & Isa, 2017). This emphasises their internal nature. Concepts are mental constructs, thus the learning of them is brain-centred, although it may be assisted through practical experiences. Certainly, we know that a concept becomes meaningful to a learner when there are many opportunities to experience examples or instances of it (Agbo & Isa, 2017; Erickson, 2008).

According to Erickson (2008, p.28), a concept is "a mental construct that is timeless, universal, and abstract to different degrees". Thus, concepts are "high level abstractions expressed in verbal cues and labels, e.g., interdependence, cultural change and causality" and are "the foundational organizers for both interdisciplinary curriculum and single-subject curriculum design" (Taba 1966, p.48). Taba goes on to refer (p.49) to generalisations and principles as the main ideas of the content under study, and suggests that curriculum content coverage could be focused by allowing the main ideas - the generalisations – to determine the direction and depth of the teaching. (These generalizations are also called "enduring understandings" by Wiggins & McTighe (2005), "essential understandings" by Erickson (2002, p.46), or "Big Ideas" in the terminology used by many curriculum designers)

Principle:
Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings", "essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.

Because concepts are "highly contextual and subject to change through time", choosing which concepts are appropriate for a particular age / phase / ability of learner requires a "value judgment" on the part of teachers (Milligan and Wood 2010, p.492). Such judgements can be particularly challenging in international school settings, where teachers are often from different cultural and geographical backgrounds (Sunder, 2015). The notion of a "concept" (or the concept of a concept!) encompasses a wide range of possible choices, varying in terms of their level of abstraction and/or universality (Little, 2017). Taba and her colleagues (Taba et al, 1971) drew a distinction between "key concepts" as larger, more universal, abstract concepts (e.g., change, power, truth) and the more "everyday" concepts which are more concrete and usually more specifically tied to particular disciplines and contexts. Gütl and Garcia-Barrios (2005) have termed this as a distinction between Fundamental Concepts (or Low-level Concepts), which are formed directly from perceptual information, and High-level Concepts, which are defined through the process of abstracting and representing an advanced state of knowledge. Erickson (2002) uses the terminology "macroconcepts" and "microconcepts." The selection of concepts has been debated in the literature (e.g. Little, 2017) and the precise choice will depend on the perceived context and purposes of a curriculum. It is clear, however, that there does need to be a choice. Tan and Tan (2017) argue that, as conceptual thinking involves learners in making connections between concepts they are already familiar with and new ideas that may challenge these concepts, it is thus very important to ensure that learners understand properly the basic concepts and can make connections between them: that is, they are taught to think and learn conceptually. It follows from this that it may be more beneficial for learners if planned curricula focus on the in-depth exploration of a few key concepts in each subject rather than try to cover a great deal of material in a superficial way. "Short units on specific topics do not give students enough time and disciplinary depth to achieve the deeper, qualitative understanding of the concepts being taught. On the contrary, it encourages the memorisation of facts and it is likely to lead to logical incoherence and misconceptions" (Tan and Tan, 2017, p.17).

Principle:
Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. It is important that some emphasis be given in teaching to the more over-arching concepts rather than trying to cover lots of material in a superficial way.

In addition to the issue of concept choice, some other principles, derived from cognitive science research into learning, have also emerged as guidance for the teaching of concepts (Smith & Zeng, 2004). These are:

- Domain-specific learning: Students learn best when concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general (Mayer, 2001). This will afford learners the opportunity to make the necessary conceptual connections as they build their webs of understanding in a discipline. This understanding will be enriched by learners being asked to make transdisciplinary connections also, but it seems to be crucial that initial understandings are 'situated' (Vincini, 2003).
- Authentic learning: Students learn best when concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned. This suggests the importance of constructing a learning environment in which specific problems are presented in ways which motivate the use of sets of concepts and interrelationships to solve these problems.
- Scaffolded learning: Students learn best when the difficulty of a task meets their capabilities. This does not imply that students should only be presented with tasks within their capabilities (much curriculum material will be challenging for them all). The concept of scaffolding, however, implies that students of differing levels of ability will need different kinds, and intensity, of support in order to complete learning tasks successfully.

Principle:
Students learn best when:

1. concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general;
2. concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned;
3. the difficulty of a task meets student capabilities.

Research question 2: How can the development of concepts in educational settings and conceptual understanding in specific areas be assessed in ways appropriate to the particular learners?

Assessment in education

In education, feedback to learners can all too often be limited to the marks / grades given to written work or the publishing of final scores on an examination. The emphasis is placed on the scores or marks achieved and often little attention given to the conceptual understanding achieved by a student. This is the problem which concept-based assessment tries to rectify (Nair et al, 2015).

It cannot be denied, however, that assessing students' understanding can be very challenging, both as a summation of their development over a fixed period and as a means of making individualised responses to meet their day to day learning needs. Learners may not yet have coherent knowledge structures in their studied subjects and their intuitive beliefs (spontaneous concepts) may well be triggered faster than their academic knowledge (scientific concepts). Consequently, their answers in examinations or tests, often produced under conditions of stress, may not reveal their emerging understandings but instead simply their intuitions (Talanquer, 2017). There is a real possibility, therefore, that examinations or tests will fail to assess student understanding adequately, and even students will sometimes claim that they are able to pass examinations without actually understanding the material being examined (Kinchin, Baysan, & Cabot, 2008). There have been some attempts to develop frameworks (taxonomies) to classify the level of understanding which students may demonstrate with regard to concepts in different disciplines.

Principle: Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.

Perhaps the best known of these has been the Structure of the Observed Learning Outcome (SOLO) taxonomy, developed by Biggs in the 1980s (Biggs & Collis, 1989). This aimed to provide a systematic way of describing how a learner's performance grows in complexity when mastering tasks of the sort frequently undertaken in school. The taxonomy suggests a general sequence in the growth of the structural complexity of concepts with understanding ranging across 5 levels: as shown below:

SOLO 1: Pre-Structural Level	The student does not have any kind of understanding, uses irrelevant information and/or misses the point altogether
SOLO 2: Uni-Structural Level	The student can deal with one single aspect and make obvious connections. The student can use terminology, recite (remember things), perform simple instructions/algorithms, paraphrase, identify, name or count.
SOLO 3: Multi-	The student can deal with several aspects but these disconnected. He/she is able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, etc.

Structural Level	
SOLO 4: Relational Level	The student may understand relations between several aspects and how they might fit together to form a whole. The understanding forms a structure and may thus have the competence to compare, relate, analyze, apply theory, explain in terms of cause and effect.
SOLO 5: Extended Abstract Level	The student may generalize structure beyond what was given, may perceive structure from many different perspectives, and transfer ideas to new areas. He/she may have the competence to generalise, hypothesise, criticize or theorise.

SOLO is claimed to be applicable in measuring the cognitive learning outcomes in different subjects among different levels of students and on different types of assignments. There is research to support this claim at higher education level (Chan et al, 2002). At school level, the main research using the SOLO framework has been that carried out in New Zealand as part of the ASsessment Tools for Teaching and Learning (asTTle) project, later developed into a digital set of tools (hence – e-asTTle). One report arising from this project (Hattie & Brown, 2004) provides some exemplification of the kinds of assessment tasks related to the SOLO framework, as shown in the following table.

SOLO 2: Uni-Structural Level	Who painted Guernica?
SOLO 3: Multi-Structural Level	Outline at least two compositional principles that Picasso used in Guernica.
SOLO 4: Relational Level	Relate the theme of Guernica to a current event.
SOLO 5: Extended Abstract Level	What do you consider Picasso was saying via his painting of Guernica?

The report has this to say about the taxonomy:

> *SOLO is a hierarchical taxonomy based on an analysis of the structural characteristics of questions and answers. It identifies characteristics of increasing quantity and quality of thought, and it is critical to note that both surface and deep cognitive processes are needed when mastering school work; it is not the case that Surface is Bad, Deep is Good. It is a cliché, but it is difficult to be deep without some surface material to think deeply about. Students must be able to master both surface and deep thinking and they can gain such proficiencies if teachers require, through their questioning of learning and/or via the nature of the assessment tasks, students to develop both surface and deep thinking. (p.26)*

Examinations tend to focus on recall of facts, whereas as we have seen, understanding involves at the least some reflection on those facts and some attempt to use them in reasoning. A single testing instrument is unlikely, therefore, to be sufficient for summative or formative purposes, especially if the instrument consists mainly of multiple-choice, factual items. Different tools are necessary to explore the state of students' knowledge (Talanquer, 2017).

Principle:
A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.

Assessment tools

It has been suggested (Mucenski, 2004) that if the goal of a curriculum is to develop students' concepts about the world then a more appropriate form of assessment will be to ask students to use their reasoning skills to construct new conceptual structures based on their prior beliefs and newly learned information. Such assessments have been termed "authentic assessment", defined by Wiggins (1993) as "Engaging and worthy problems or questions of importance, in which students must use knowledge to fashion performances effectively and creatively. The tasks are either replicas of or analogous to the kinds of problems faced by adult citizens and consumers or professionals in the field (p. 229)." The term 'authentic' can also imply that the techniques used to assess students' progress must also match the form and nature of the teaching they have received. This means that assessment procedures must be consistent with the CBTL cycle. The research literature provides and evaluates many forms such assessment may take, several of which are quite innovative and can be used throughout the 'learning cycle' to measure students' progress as learning occurs (Marek, 1999, p.15). The assessment procedures reviewed here are: feedback, semi-structured interviews, guiding questions, open-ended essays, think-aloud problem solving, graphic organisers, concept maps, KWL charts, free word associations, similarity ratings, card sort, word clouds (cf. Mucenski, 2004)

Feedback

Assessment is a powerful part of the teaching process and feedback is an integral part of formative assessment, which helps both the teacher and the students to make meaningful changes and to improve the teaching-learning process (Wiliam et al, 2004). Numerous studies have suggested that, for feedback to be effective, it needs to be "goal-oriented, actionable, personalized, timely, ongoing and consistent" (Nair et al, 2015, p.848). The Nair et al study focused upon a system for the assessment of learning at the concept level in order to provide students with specific, targeted, and ongoing feedback on their strengths and weaknesses in terms of their abilities to apply the concepts they were learning. The results demonstrated that feedback appeared to benefit students' recall of concept terminology and their abilities to classify both previously studied concepts and new examples of these. But the form of feedback which worked best was that which did more than just correct a mistake, but deliberately elaborated with a new example of the concept in action. Where this occurred learners were able to deepen their conceptual knowledge, which led to improved recall of previously studied information as well as their abilities to apply their knowledge to novel situations. A similar positive outcome emerged from the study by Finn et al (2018) in which learners answered a test question, received feedback on the correct answer and then were presented with a further example of the concept. Finn et al speculate that allowing the learner to review the correct answer feedback first, and then receive some elaboration including a concept example, may have helped them more easily to integrate the new idea into their conceptual schemas.

Principle:
One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.

Semi-structured Interviews

Jonasson (2006), in a thorough and revealing essay about concepts and conceptual change, suggests that a powerful method for assessing concepts-in-use is to conduct semi-structured interviews with learners, using generative questions. This is a familiar approach in much child development research, and the findings of researchers such as Piaget were derived using this method. Vosniadou (1994) reported presenting different pictures of a stone and a stick figure and asking questions to young learners such as, "Is there a force exerted on the stone, and why?" Such an open-ended approach can allow learners, in explaining their reasoning, to reveal a good deal of information about their current conceptual frameworks.

Guiding questions

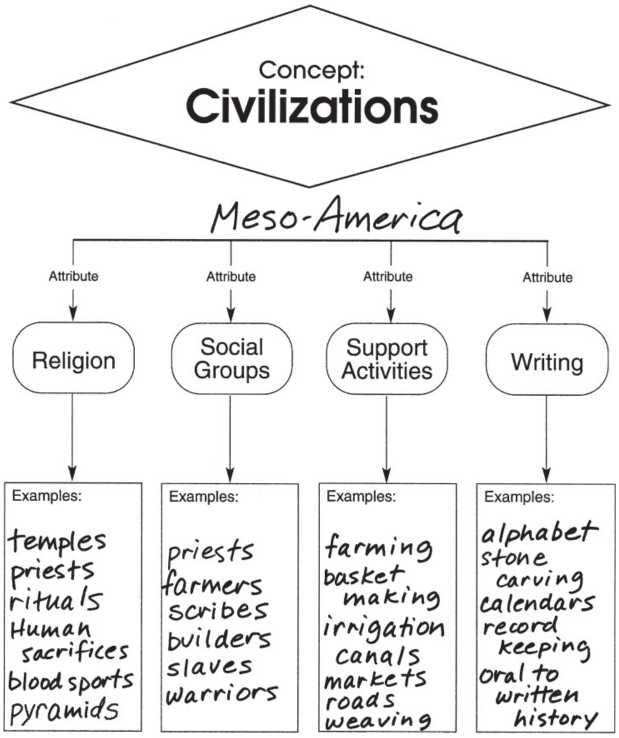
Another way to assess the conceptual understanding of learners is through the use of guiding questions. These will be open-ended and deliberately aim to develop learners' thinking from concrete to more abstract levels. Erickson (2007) suggested the use of three types of questions:

- factual questions – "What materials do farmers put on their fields to help their crops grow better?"
- conceptual questions – "What do these materials have in common?"
- provocative questions – "Do you think it's a good thing for farmers to do this all the time? What problems might it cause?"

While factual questions are necessary for development of content knowledge, conceptual and provocative questions can encourage learners to develop inquisitive minds and go beyond the remembering of facts in their learning as they seek more complex and in-depth understanding (Yak-Foo & Koh, 2017).

Open-ended essays

McCoy and Ketterlin-Geller (2004) report on their study of an episode of concept-based teaching and make the point that, given the rich complexity of learning expected from their students, it would be very difficult assess these students' growing conceptual understanding using simple multiple-choice or short-answer questions. Their approach was to combine the use of graphic organisers (see below) with open-ended essays, marked using a scoring guide. The approach is best illustrated with an example from their article. As part of a study unit on Civilisations, 12-year-old Fred summarised the material he had been reading about Meso-America in the following graphic organiser:



Fred then wrote the following open-ended essay using what he had learned:

> I found my island in the Pacific Oceon People all ready lived there. They heard that I have read about the early civilization of amicas-omecs, Mayas, Aztecs, and Incas. They think I know about four important feature of civilization. Peoples belief was that the temples were religion. People lived together by building a small villige so they can support themselves. By the water the put a farmed land farmers go fishing a lot that's also another thing they support them selfs they had trails to go from one city to the other., People communicated with writing language that is colled hieyoglyphics that how they know how to get from one village to the other by putting signs with hieyroglyphics.

McCoy and Ketterlin-Geller report that students studying the content material using a concept-based approach performed much better on open-ended assessments such as this, which required them to illustrate the concept in a new way, demonstrating higher-order thinking.

Think-Aloud Problem Solving

As an alternative to interviewing students, they can, according to Jonassen (2006), be asked to think aloud while they are solving problems. Think-alouds, as the term implies, involve participants thinking aloud as they are performing a set of specified tasks. Participants are asked to say whatever comes into their mind as they complete the task. This might include what they are looking at, thinking, doing, and feeling. This gives observers insight into the participant's cognitive processes (rather than only their final product), to make thought processes as explicit as possible during task performance. The author admits that this can be a somewhat artificial and difficult activity. Most learners do not verbalise their thinking in this way while engaged in complex activities. Even the originators of the use of Think-Alouds in research (Ericsson & Simon, 1998) admit that there is evidence that it is only possible "under *some* circumstances" (p.178) for participants to think aloud without altering the course of their thinking.

A more natural method that can produce extensive information about learners' conceptual frameworks is thinking aloud *paired* problem solving (Whimby & Lockhead, 1999). Working in pairs, one student thinks aloud while solving a problem. Thinking aloud requires the problem solver to vocalise as many as possible of the methods, inferences, or conclusions that he or she is constructing or recalling while solving a problem. The other pair member listens to his/her partner's thoughts and asks questions or comments on apparent inconsistencies at appropriate moments. Having a classmate spot your mistakes in this informal situation can be a great deal less off-putting than having your teacher listen to you.

Principle:
Talking to learners, whether through structured interviews, guided questions, or encouraging thinking aloud is one of the most effective ways of accessing their thought processes.

Graphic organisers

Graphic organisers are tools that can help learners to organise their ideas, either before a course of study, or immediately following it, when they can reveal a good deal about the learner's conceptual structure (Yak-Foo & Koh, 2017). According to Gallavan and Kottler (2007), the use of graphic organisers in social studies can increase learner motivation, help short-term recall and show more long-term achievement. In addition, graphic organisers can help learners to summarise and manipulate information so the learning of terms, structures and functions becomes more manageable and memorable. Yak-Foo and Koh (2017) argue that concept learning is enhanced when learners are better able to visualise the complexity of a system and visualise the "big picture" or "pattern" of all the parts involved in a system. Decades of research with various age groups and in different content areas has shown that, in general, when graphic organizers are incorporated into teaching, student learning improves (Hall & Strangman, 2008).

Graphic organizers also help teachers meet the needs of all learners. Presenting information in both text and graphic formats is one of the most basic ways to make a lesson accessible to more students. In fact, much of the research on graphic organizers has focused on how powerfully they can impact the learning of students with learning disabilities and special needs (Dexter, Park, & Hughes, 2011; Douglas, Ayres, Langone, & Bramlett, 2011).

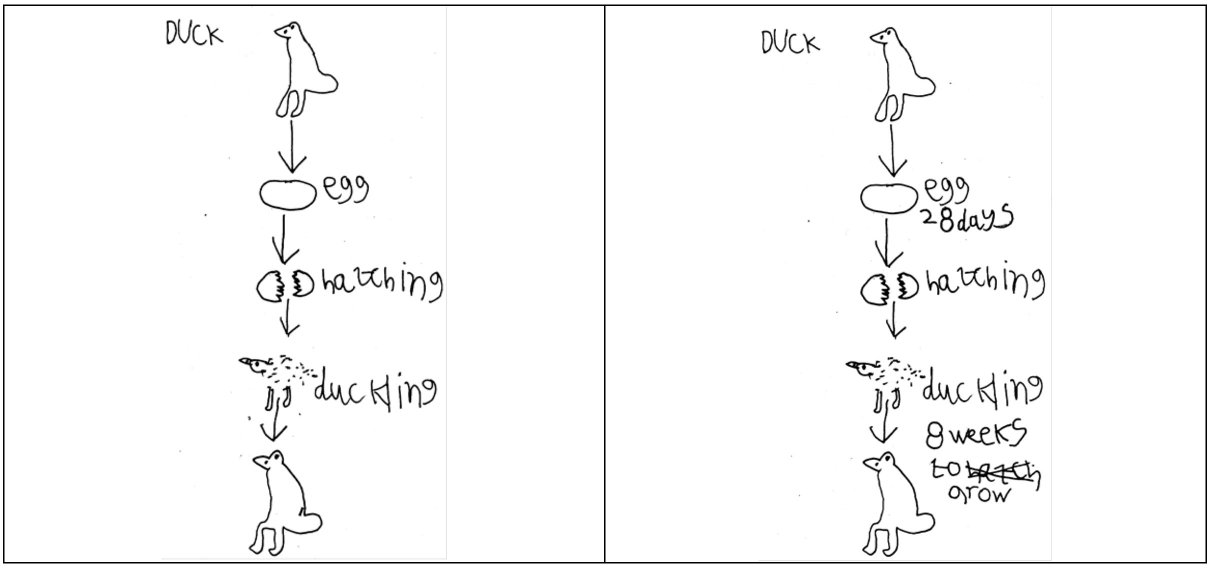
Gonzalez (2017) provides a selection of sample graphic organiser templates, and also suggests that they can be used as a means of assessment of student learning. Because graphic organisers focus upon the relationships between items of content and ideas, they can provide an illustration of the relationships and concepts that the student has mastered. Two examples, taken from the work of Wray and Lewis (1997) will illustrate this.

The first is from work done by a class of seven-year-olds, studying Food Sources in the UK. One of the boys has represented his findings about hedgerow food sources by the means of the following diagram. This suggests the ability to classify information and thus suggests a level of conceptual understanding.

His classmate, however, has noticed that, although rose hips are properly listed as inedible, they can, of course, be made into rose hip syrup, which is certainly edible. He therefore represents his findings in a different diagram:

Rose-hips now span the poisonous and edible columns, which suggests a deeper conceptual understanding of the information learnt.

The second example is from a six-year-old student who has been involved in a unit of work on change, and has been studying the ways in which various animals change through their life cycles. She produced the following two diagrams to show the life-cycle of a duck:



The diagram on the right is a revision of that on the left, after the child was encouraged by her teacher to add some indication of time scale to her model. The conceptual learning here is shown more though the graphic elements of her diagrams, particularly the use of arrows to indicate changes in the animal.

In a study of 40 social studies teachers (Ilter, 2017), who used concept-based methods of teaching, participants were asked to respond to the question: "Which assessment tools or practices do you use to assess how well your students have learned the concepts in your classrooms?" Thirteen of these teachers claimed to use a range of graphic organiser tools for this purpose, although they did not use these exclusively, all mentioning also using the more traditional methods of "multiple-choice matching tests, fill-in-the-blanks, multiple choice tests, and true-false tests" (p. 1152). Some of the teachers in this study claimed that graphic organisational tools were particularly useful for measuring students' word meaning and vocabulary skills.

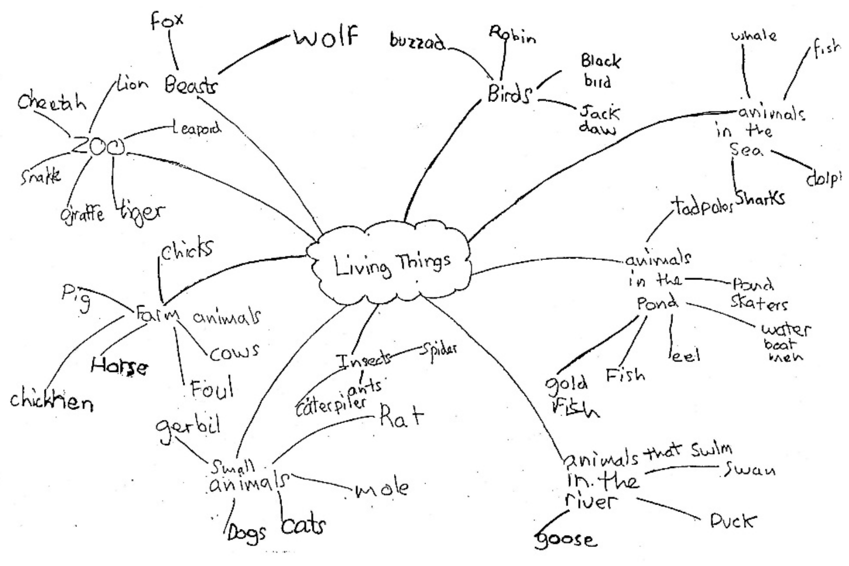
Concept maps

Concept maps are in essence a particular form of the graphic organiser. They were introduced by Novak and Gowin (1984), based upon Ausubel's (1963) meaningful learning theory which states that 'Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures'. According to Novak and Gowin (1984:15) the concept map is a 'schematic device for representing a set of concept meanings embedded in a framework of proposition.' It clearly emphasizes the relationships between concepts (Nair & Narayanasamy, 2017).

In a concept map, the concepts are represented by nodes and the relationship between each pair of nodes is presented by a directional arrow indicating a meaningful proposition. In most concept maps, the concepts are usually arranged in the form of a hierarchy, where a higher-level concept is placed near the root of the hierarchy, often at the centre (Novak & Gowin, 1984). Concept mapping has been used to foster learning in a number of ways, including to promote curriculum development (Riesco, Fondon, & Alvarez, 2008), develop teaching strategies (Stoddart, 2006), improve problem solving (González, Palencia, Umaña, Galindo, & Villafrade, 2008), and teach specific content (Kyrö, Seikkula-Leino, & Mylläri, 2008). The evidence supporting its use in these ways will be explored elsewhere in this review (See p.66) (See also Roessger et al (2018) and Hwang et al (2014).

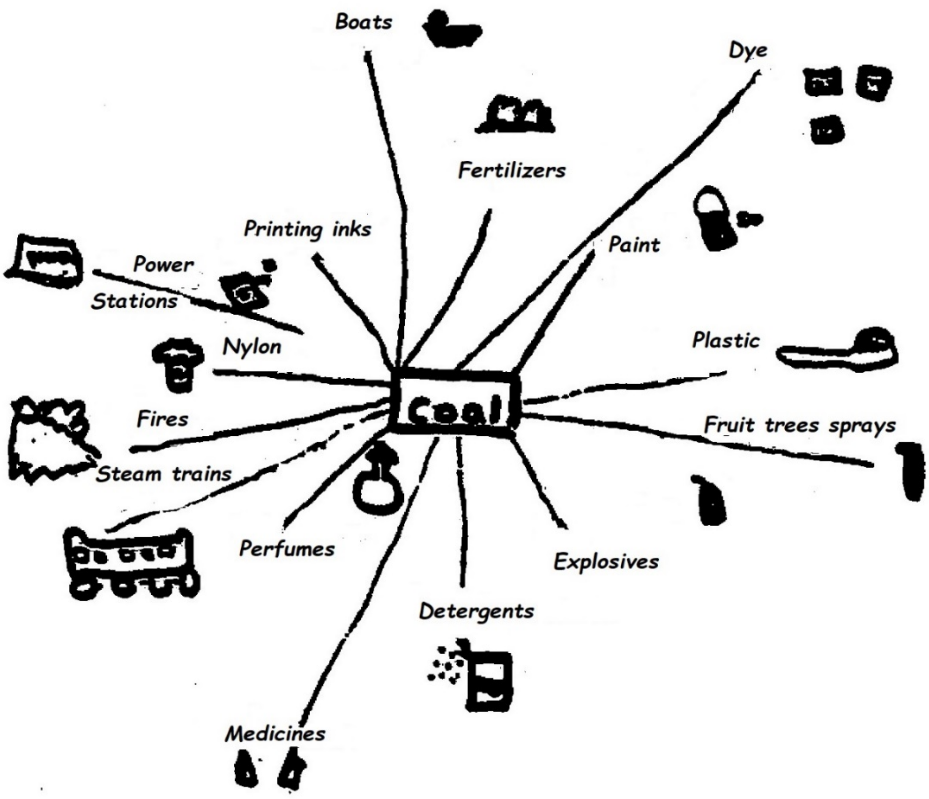
Concept maps have also been used extensively to assess learning (West, Park, Pomeroy, & Sandoval, 2002), in particular, knowledge acquisition and knowledge organization (Daley & Torre, 2010; Knollmann-Ritschel & Durning, 2015; West et al., 2002). In a review of the literature, Ruiz-Primo (2004) concluded that concept maps were valid and reliable measures of how well students mentally organize the knowledge in a domain. McClure, Sonak, and Suen (1999) found that, when educators used certain scoring methods, concept maps were valid and reliable measures of not only students' knowledge organization but also their retention of course content. Additionally, Stoddart, Abrams, Gasper, and Canaday (2000) demonstrated that concept maps were practical, valid, and reliable measures of a student's understanding in a given domain. Taken together, these findings suggest that concept maps measure aspects of learning that illustrate the changes in a student's understanding resulting from teaching. Roessger et al (2018)

The idea of using the concept map to plan teaching can also lead into later use of it for both formative and summative assessment. Rye et al (2013) found that the middle and high school science teachers in their study identified concept maps as a useful tool for assessment early in a teaching unit. Assessing what students already knew about a topic was seen as a highly valuable activity by these teachers, leading directly into their planning. As an example of this, the following concept map was produced by an eight-year-old at the beginning of a unit on Living Things (Wray & Lewis, 1997).

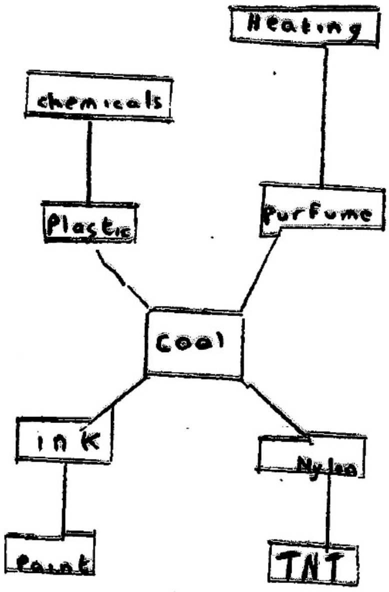


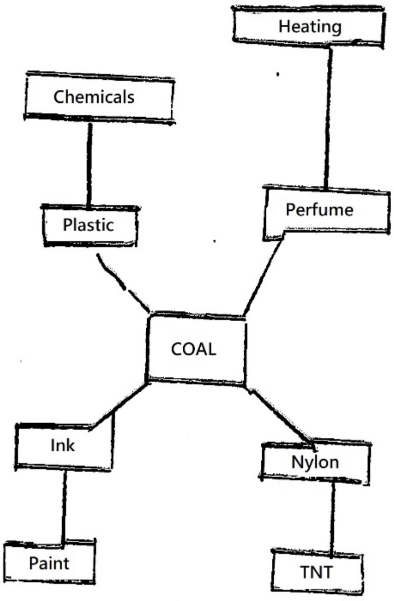
It can be seen that this student already had a good deal of knowledge about this topic, knowledge which she was able to organise conceptually through classification. The fact, however, that plants do not feature in her initial conceptual structure of living things was useful information for her teacher in terms of planning activities to advance her understanding.

Concept maps can also be an extremely useful instrument for measuring significant knowledge acquisition as a result of study, as they make it possible to view how well structured the knowledge is and how valid the relationships are that are established within the new knowledge (Edmonson, 2005; Romero, 2017). Again, a simple example of this from Wray & Lewis (1997) can be seen in the following 3 concept maps produced by seven-year-old children after some study on the subject of Energy. The maps represent their understandings of the uses made of coal. In the first example, the child has simply used the concept map format to list the uses of coal. The map thus shows her extensive knowledge but does not indicate anything of her conceptual structure in this topic.

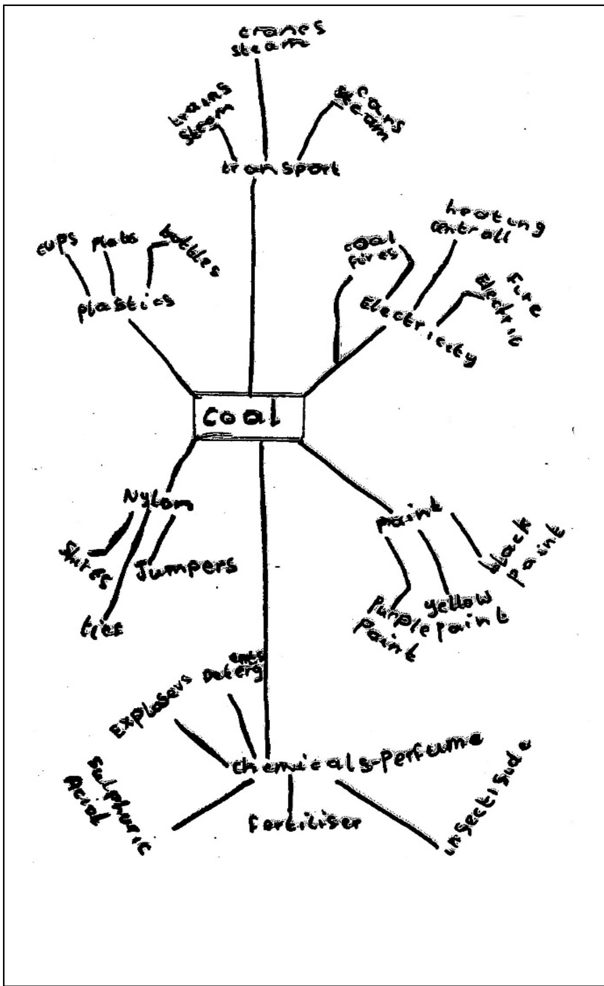


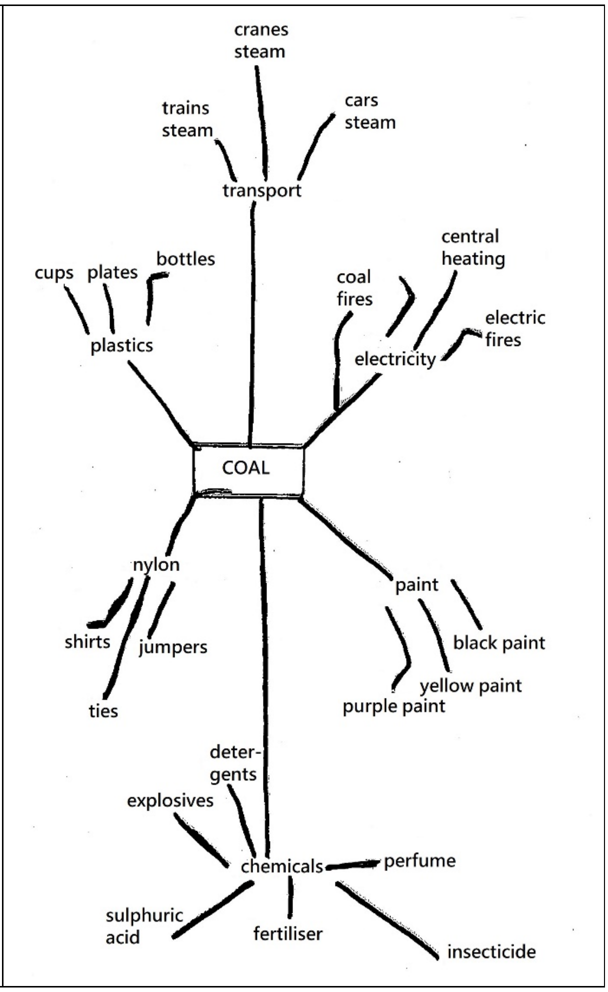
In the second example, the child has tried to group together the knowledge he has gleaned about the uses of coal but the relationships he draws between items, and hence his likely conceptual structure, are not very useful or accurate.





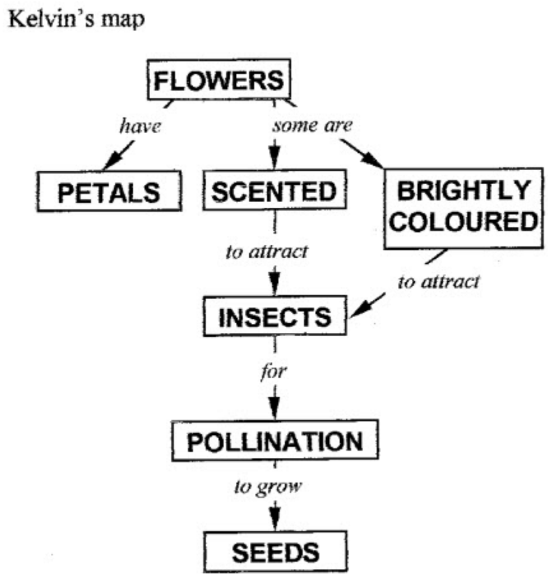
In the third example, though, the child has gone beyond straightforward facts about coal and has indeed tried to organise these into like groups, even on occasions using the concept map structure to go beyond the material he actually studied.



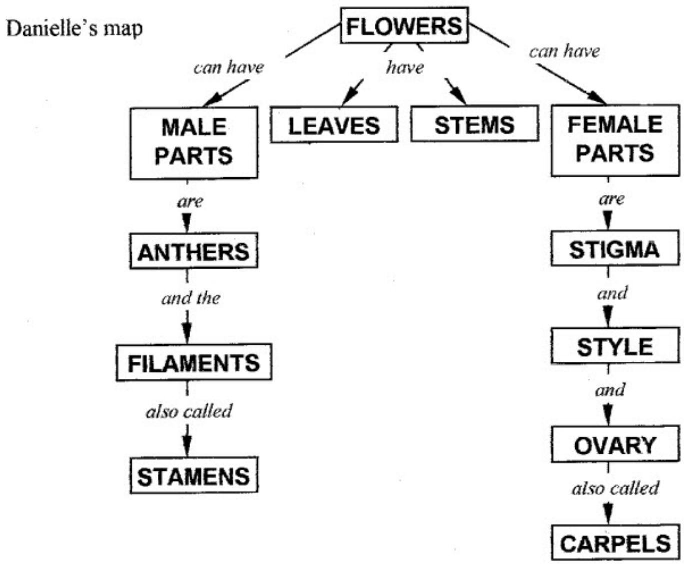


The concept mapping activity reveals different modes of thinking among these three learners.

Kinchin et al (2000) provide an example of such differentiation using the concept maps produced by three secondary school Science pupils. They argue that concept mapping is a tool that can help to make student understanding explicit and these concept maps were produced by pupils on the subject of reproduction in flowering plants.

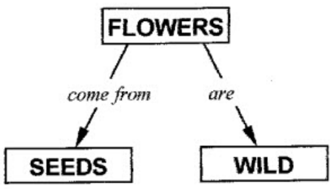


Kelvin's map is dominated by a chain showing an appreciation that flowers need to attract insects for pollination, suggesting a focus on one particular section of the lesson he had experienced.



Danielle's map is characterized by two chains showing an appreciation of the male parts of flowers and a separate appreciation of the female parts of flowers. These are shown as distinct sequences with the lack of overlap emphasized by the positioning of the chains so far apart in her map. While the interrelationship between male and female may seem obvious to the teacher, Danielle has failed to make this connection and so appears to have missed one of the key points of the reproduction process. This suggests that perhaps the lesson experienced did not make enough of the links between aspects of the subject, relying on students to make those links for themselves. It can be seen from Danielle's and Kelvin's maps that when such links are not emphasized, different students will take different elements from a teaching sequence upon which to base their individual knowledge structures.

Simon's map



In comparison to Danielle and Kelvin, who both have well-developed knowledge structures covering certain components of the topic, Simon's map suggests that he has failed to internalize the details of reproduction in flowering plants in terms of sexuality or in terms of the relationship between flowers and insects.

Concept maps can, therefore, measure students' understanding of the complexity of concepts, and interrelationships (Ruiz-Primo et al, 2001). Tan et al (2017) report that the repeated use of concept maps in their study increased the complexity and interconnectivity of the concepts expressed by learners, independent of science content, and they argue on this basis this tool is more appropriate than the traditional assessment methods to use in science. Ritchhart et al (2009) concur with this view, concluding from their research that "Our examination of hundreds of concept maps has shown that they are indeed rich vehicles for uncovering students' conceptions of thinking in a way that is accessible both to teachers and students" (p.156).

Principle:
Asking students to express their ideas graphically can also provide a powerful window into their thought processes and understandings. This can involve the use of graphic organisers or concept maps.

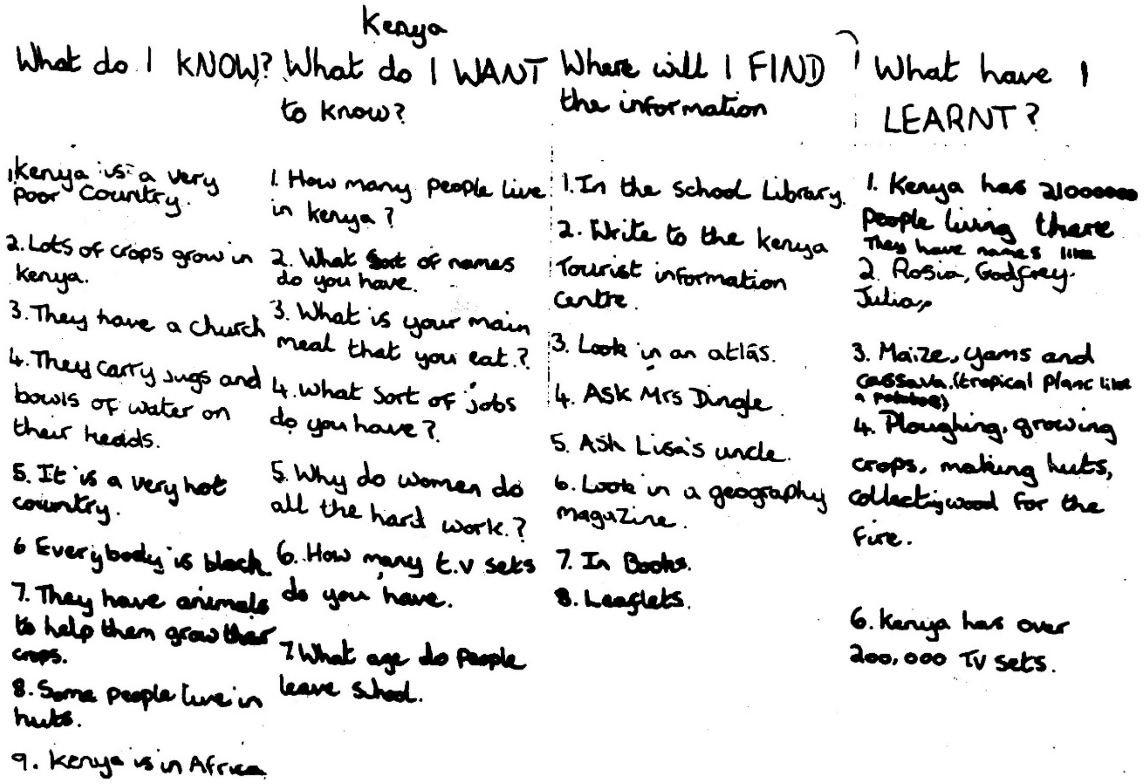
KWL charts

The use of K-W-L charts can also allow teachers to identify student misconceptions about a topic before study of it begins. KWLs were first developed by Ogle (1986) as a tool to help with purposeful reading of expository text and their classic form is shown below:

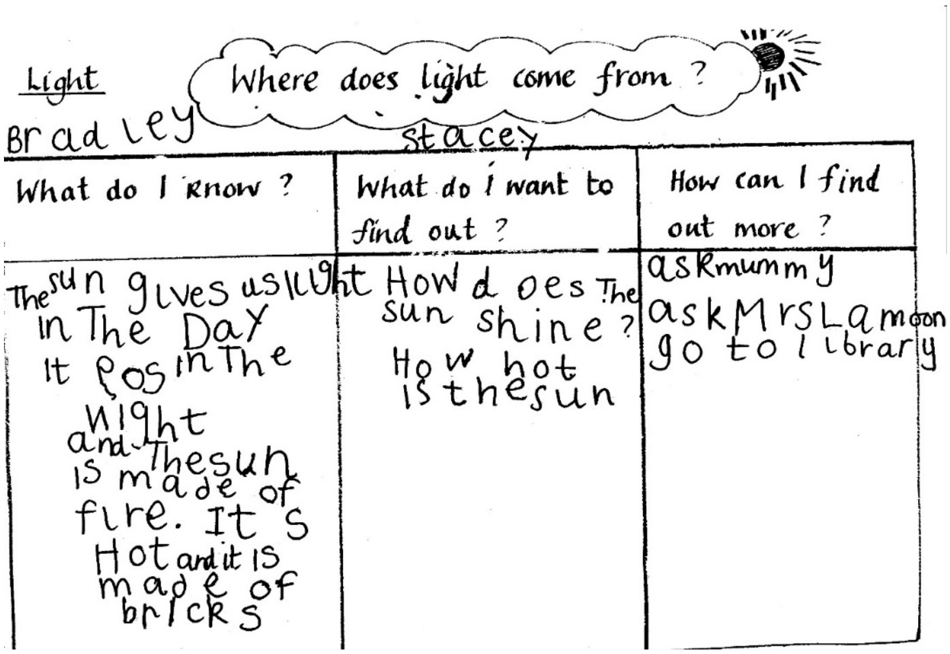
K What I know	W What I want to know	L What I learned
Students write what they already know about a topic in this space.	Students write what they would like to know in this space.	Students write the information that they have learned in this space (i.e. the answers to their questions in the W column)

Using the material which students write in the first column of the chart, a teacher can develop teaching materials tailored to their existing knowledge, or misconceptions. The second column can enable students to be specific about the focus of their subsequent study, and the third can provide the teacher with a summary of what has been learnt (Mucenski, 2004).

There have been developments to the original KWL format. One form included in the research of Wray and Lewis (1997) was the KWFL – with the F column inviting learners to specify where they might find the information they are looking for. An example of this in practice is given in the figure below, which is the recording made by one ten-year-old as part of a study topic on the country of Kenya. Readers might wonder why Mrs Dingle and Lisa's uncle are listed as potential sources of information! But, of course, learners learn things from other knowledgeable people as well as from books or the Internet.



This technique can also be adopted to the needs of quite young children. Bradley and Stacey, for example were both not quite six years old when they became interested in Light.

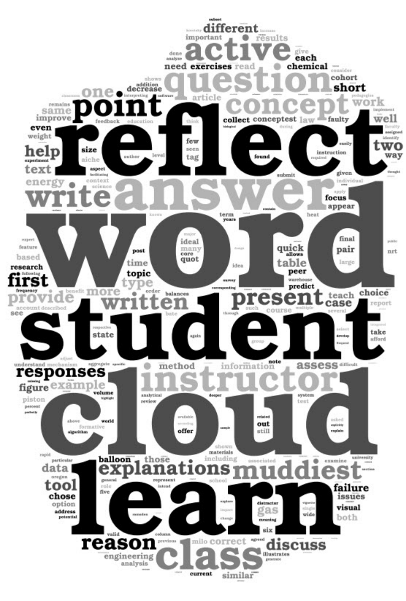


Again, people figure largely as sources of information.

Principle: Learners can be asked to represent their on-going understandings in more structured ways through devices such as KWL grids and word clouds.

Word clouds

A word cloud is an image made of words that together resemble a cloudy shape. The size of a word shows how important it is e.g. how often it appears in a text - its frequency. People typically use word clouds to produce a summary of large documents (reports, speeches), to create art on a topic (gifts, displays) or to visualise data (tables, surveys). Brooks et al (2014) exemplify the word cloud technique by providing a word cloud summary of their article:



Freely available web sites (e.g. https://www.wordclouds.com/ and http://www.wordle.net/) can generate word clouds from any inputted texts.

Several research studies have demonstrated that word clouds can provide a quick analytical technique to begin assessment of student written explanations and reflections (e.g. Clough & Sen, 2008; Chuang et al 2012; McNaught & Lam (2010). Ramsden and Bate (2008) provide a useful set of guidance notes on the use of word clouds.

Research question 3: What models of CBTL have been proposed and how do these align with typical concept development?

What has been discussed so far suggests that there has been a paradigm shift in terms of models of successful teaching and learning. It seems to make good sense to teach conceptually – which, however, begs the question of what constitutes conceptual teaching? Erickson (2002, 2007, 2008) refers to this as concept-based instruction and argues that it goes beyond mere fact acquisition, focusing rather on the teaching of the "big ideas" of a subject, using appropriate content, information or facts to support the learning of these ideas. Teachers, it is claimed, do not have to teach all the factual content in a subject. Instead, they need to select and reorganise the content relevant to learners' understanding of these big ideas. Concept-based teaching, or conceptual teaching (Hwang, 2016) is conceived as a form of inductive teaching in which learners are guided to understand the big ideas rather than being taught directly about these ideas. The resultant learning helps students both to retain understandings and to transfer this to other contexts. The big ideas of a subject take the form of concepts and generalisations.

In a traditional classroom where the norm will tend to involve direct instruction, teaching is often topic-based and may involve covering the subject content prescribed in a textbook in a sequential manner. Such an approach means that all the content is seen as important and has to be covered; the end goal for students is knowledge acquisition; this knowledge is taught discretely with teachers rarely helping learners to make broader connections to the rest of the curriculum or even to their previous knowledge and experiences; there is limited transfer of learning. In concept-based teaching, the aims are completely the opposite. Here teaching focuses on concepts and generalisations, with teachers selecting and reorganising specific and relevant content material to support the learning of the identified big ideas. They may tell their students up front what the concepts and generalisations are, then provide them with sufficient content material (or enable them to locate this themselves) to enable them to 'flesh out' the key concepts with facts etc. Or they may guide their students through appropriate activities to help them arrive inductively at an understanding of the big ideas. In either event, the teachers' role is to assist students to see patterns and connections between the concepts and generalisations and make links to other parts of the curriculum and to students' lives. Learning is therefore more connected and meaningful and also more powerful as it can be applied widely.

Principle:
Concept-based teaching is conceived as a form of inductive teaching in which learners are guided to understand the big ideas rather than being taught directly about these ideas.

In her seminal work carried out more than 40 years ago, Taba (1962) emphasised the need to focus more on conceptual understandings rather than merely teaching facts. This view is now echoed in the international literature on CBTL (e.g. Avery & Little, 2003; Erickson, 2002, 2007; Wiggins & McTighe, 2005). Which does not mean, of course, that there is only one model of how such teaching and learning should be implemented. In the remainder of this section, a range of alternative models of concept-focused teaching and learning will be examined and, where possible, research evaluations of these models will be discussed.

Models of concept-based teaching

1. Applebee curriculum integration model

Applebee's (1996) discussion of curriculum reflects the intended outcomes of a concept-based curriculum (even though he does not mention the term) and what students ought to be exposed to, and to engage with. He argues that curriculum, 'rather than stressing knowledge as a body of information to be mastered, should conceive of knowledge as action, of activity in cultural practices, traditions of discourse through which students are enculturated to the values of academic disciplines' (p. 9). This is what we would now consider a concept-based curriculum. For Applebee, curricula should not consist of 'catalogues of items, collections of information, sequences of events, and episodes of occurrences'. Rather, they should be organised to enable students 'to integrate knowledge through participation in an extended conversation, to discover interrelationships across all of the elements in the curriculum', and as new elements enter into the conversation, 'they provide not only new contexts for exploring or redefining the established topic, but new perspectives on other elements in the conversation, and on the topic itself'. Such conversations have four key characteristics:

- They are built around language episodes of high quality.
- They have an appropriate breadth of materials to sustain conversation.
- They include a variety of parts that are interrelated.
- They include instruction that is geared to promote students' entry into the curricular conversation through such processes as instructional scaffolding (p. 77).

When there is a shift in the focus of the curriculum from bodies of knowledge to be mastered to questions and themes forming the basis for discussions, students have to manipulate and synthesise what they have learnt. Assessments will need to change from a focus on knowledge of a subject to knowledge-in-action, that is, students' abilities to define interesting questions, express a clear point of view, gather evidence and structure arguments according to disciplinary conventions. One can therefore expect a concept-based curriculum to be anchored in concepts, not to be crowded by excessive subject content focusing predominantly on factual knowledge, and to adopt student-centred pedagogy based on inquiry instead of direct teaching dedicated to the delivery of a body of content. One would also expect to see activities that generate discussions based on probing questions posed by students, tasks that challenge students to express their opinions, synthesise their learning and apply their understandings to new, novel contexts.

Principle: Curriculum should not stress knowledge as a body of information to be mastered, but rather as the joining in with traditions of discourse through which students are enculturated to the values of academic disciplines, and it should be organised to enable students to integrate knowledge and discover interrelationships across all elements.

2. The 5E Teaching Model

Reports on the use of concept-based teaching have begun to appear increasingly in the educational research literature, relating to a wide range of curriculum subjects and age phases. Ampartzaki and Kalogiannakis (2015), for example, report on their work with young children on Astronomy. So as to avoid, as they put it, "the mistake of watering down content that is more appropriate for older children" (p.170) they used a concept-based approach to astronomy which they believed would lead to deeper understanding and meaningful learning. Their teaching methods involved the use of modelling, demonstration, explanation and questioning, set within the 5E teaching model (Biological Sciences Curriculum Study (BSCS) 2006) which uses 5 phases of activity, namely:

• Engagement: Children encounter with a topic and bring up their preliminary understanding.
• Exploration: Children search in a variety of sources and different ways to find answers or verify their initial perceptions/knowledge about the topic.
• Explanation: Children develop evidence-based explanations about the issue at hand. Any explanations offered by the teacher at this stage aim at helping children to deepen their understanding.
• Elaboration: The purpose of this phase is to challenge children and encourage them to apply their new knowledge to a novel situation related to the topic.
• Evaluation: Although evaluation should be an on-going process, in this phase children reflect on their learning and (in partnership with the teacher) assess the level of understanding they have reached (Ampartzaki and Kalogiannakis, 2015 p.170).

Unfortunately, no details are given in the Ampartzaki and Kalogiannakis (2015) paper of any assessments made of children's learning progress following this teaching. The reason for introducing it at this juncture in this review was to make the point that CBTL has been explored with students ranging from early childhood (See Birbili, 2007 for an explicit focus on concept-based teaching with early years' children) to undergraduates.

3. The STS Approach

A teaching model which has been evaluated quantitatively is that proposed by the National Science Teachers Association (NSTA, 1991). The aims of this Science-Technology-Science (STS) approach to teaching science have been summarised (Mbajiorgu & Ali, 2003) as to develop decision-making and problem-solving skills in order to help students understand socio-scientific issues. Kapici et al (2017) compare the benefits of the STS approach with a more traditional science teaching approach and produce the following comparison table (p.22).

STS Approach	**Textbook Oriented Approach**
Students try to solve problems that are relevant to their daily lives	Teacher does not try to connect the topic with daily life
Students become involved in resolving social issues and see science as a way of fulfilling their responsibilities as citizens	Students feel no responsibility for resolving current societal problems
Students seek out information and use it in order to solve the problems	Students can recite information/concepts
Students are able to follow the developments in technology and able to see the relation between scientific concepts and technological progression.	Students cannot relate the science they study to any current technology
Teaching does not only take place at school but also supported with informal learning environments like science centres and science museums.	Learning is contained in a classroom for a series of periods over the school year
Students in science class wonder about what the future might be like.	Science class focuses on what has been previously known
Students are prompted to enjoy and gain experience through learning process.	There is little concern for the use of information beyond the classroom and performance on tests

Kapici et al (2017) present the results of their study of 609 twelve to sixteen year olds, which show that the students who experienced the STS approach in their science classes over half a year were more successful in meaningfully applying basic science concepts to new situations than were students who were taught by the more usual textbook-oriented approach. They also compare their outcomes with similar results emerging from several other studies and suggest that this teaching approach is more effective in producing students with mastery over basic and applied concepts in science.

Principle: Approaches in which students are encouraged to apply their understandings to real life problems are more successful than traditional textbook-based approaches.

4. The Graphic Organiser Model

McCoy and Ketterlin-Geller (2004) also report an evaluation of a concept-based model of teaching, with their case study focusing upon a programme of History teaching with 16 year olds, involving the use of graphic organisers. Their model is characterized by three discrete components:

1. The teacher determines the concept that is the target of instruction.
2. A graphic organizer is developed to illuminate this concept for the students.

3. Students' success in mastering the concept is measured by applying it across instances using increasingly complex critical thinking measures.

The use here of graphic organisers was explored in greater detail earlier in this review (p. 38). The key feature of this model, though, was the use of the innovative assessment tool of the open-ended essay as a means of aligning the assessment with the level of conceptual thinking that students were expected to engage in. The authors report that students presented with the concept-based approach performed much better on these open-ended assessments that required them to illustrate the concept with a new example, and were able to demonstrate higher-order thinking. The students who experienced concept-based teaching also performed as well as other students on tests of memory of facts covered in the programme. A less deliberate focus on traditional subject content had not disadvantaged these students.

5. The Integrated Curriculum Model

The Integrated Curriculum Model (VanTassel-Baska & Wood, 2010) was developed for use with gifted learners and is focused around three dimensions:
1. Emphasizing advanced content knowledge in disciplines. This will inevitably be at the conceptual level.
2. Providing higher-order thinking and processing. This is to promote student opportunities for manipulating information at complex levels
3. Organizing learning experiences around major issues, themes, and ideas that define understanding of a discipline and provide connections across disciplines.

The basic teaching process underpinning the model is constructivist in nature and involves asking students to
1) identify examples of a concept,
2) organize and reflect upon it,
3) provide counter examples of the concept,
4) develop generalizations,
5) apply those generalizations to previous and future knowledge.

The ICM is distinctive in the field not simply because it is deliberately aimed at gifted learners, but it has also received extensive research evaluation (thoroughly summarised in VanTassel-Baska and Wood, 2010). Enhanced student learning has been demonstrated in many studies, with foci of subjects from social studies to science. Although this is the primary marker of effectiveness, VanTassel-Baska and Wood also comment that teachers' favourable experiences with materials and related teaching strategies are also important and have also been very positive.

Principle:
Effective concept-based teaching processes involve asking students to:
1) identify examples of a concept,
2) organize and reflect upon this,
3) provide counter examples of the concept,
4) develop generalizations,
5) apply those generalizations to previous and future knowledge.

6. Understanding By Design

Another distinctive and popular curriculum planning model which foregrounds concept-based teaching is Understanding by Design (Wiggins & McTighe, 2005). This model has a number of distinctive features, perhaps the most influential of which has been the notion of "Backward Design" (also known as "backwards planning"). Teachers, according to Wiggins and McTighe, traditionally start their curriculum planning with activities and textbooks instead of identifying classroom learning goals and planning towards these. Backward design begins with the objectives of a unit or course—what students are expected to learn and be able to do—and then proceeds "backwards" to create lessons to achieve those desired goals. The basic rationale behind this is that starting with the end goal, rather than starting with the first lesson, helps teachers design a sequence of lessons, problems, projects, presentations, assignments, and assessments that result in students achieving the academic goals of a course or unit—that is, actually learning what they were expected to learn.

> ***Principle***:
> Backward design in curriculum planning begins with the objectives of a unit or course—what students are expected to learn and be able to do—and then proceeds "backwards" to create lessons to achieve those desired goals.

Other key features of Understanding by Design (UbD) are:

1) UbD is a way of thinking purposefully about curricular planning and school reform. It offers a 3-stage design process, a set of helpful design tools, and design standards -- not a rigid program or prescriptive recipe.
2) The primary goal of UbD is student understanding: the ability to make meaning of "big ideas" and transfer their learning.
3) Understanding is demonstrated when students autonomously transfer their learning through authentic performance. Six facets of understanding – the capacity to explain, interpret, apply, shift perspective, empathize, and self-assess – serve as indicators of understanding.
4) Teachers are coaches of understanding, not mere transmitters of content. They design for and support "meaning making" and "transfer" by the learner; and adjust to achieve intended results.
5) Regular reviews of curriculum against design standards enhance curricular quality and effectiveness.
6) UbD reflects a "continuous improvement" approach. The results of curriculum designs - student performance – informs needed adjustments.

Although Wiggins and McTighe claim huge penetration of their UbD ideas and materials, especially in the USA, there is as yet little empirical evidence demonstrating the effectiveness of their curriculum model, in terms of student achievement. McTighe and Seiff (undated) do provide what is termed "A Summary of Underlying Theory and Research Base", although this is largely taken up with reviewing the research evidence underpinning the model, rather than reporting on outcomes.

7. Erickson's Model

The final concept-based teaching model to be reviewed is that of Erickson, which has been central to the curriculum planning approach of the International

Baccalaureate Organisation (Erickson, 2012). Erickson's model is distinctive for its three-dimensional design model for the curriculum, which, she claims, allows a "focus on concepts, principles and generalizations, using related facts and skills as tools to gain deeper understanding of disciplinary content, transdisciplinary themes and interdisciplinary issues, and to facilitate conceptual transfer through time, across cultures and across situations" (p. 4). She spells out the key shifts in pedagogical thinking underpinning her model. These are:

- *Synergistic thinking* – by this Erickson means the interplay between thinking at the factual and conceptual levels, which she sees as essential. This identification of the need for synergy between facts and concepts does set Erickson apart from other curriculum designers focused on concept-based teaching. As she says, "Just knowing the definitions of concepts is not sufficient. Just knowing facts is not sufficient" (p.8). Learners need both.
- *Transfer of knowledge and skills* – as Erickson points out, facts do not transfer. They are situated in particular contexts. (Knowing the boiling point of water is not going to help a learner identify the freezing point of alcohol, or even its boiling point.) Knowledge can only transfer at the conceptual level as generalizations and principles are applied across contexts. It is possible that Erickson overstates this distinction. Researchers working from a situated cognition perspective (e.g. Brown et al, 1989) have suggested that people's knowledge is embedded in the activity, context, and culture in which it was learned. Perhaps even concepts are embedded in their contexts? The concept of multiplication, for example, has a particular meaning in mathematics which may not help a student understand its meaning in studies of population growth (Go forth and multiply!) – aside from a general sense of something getting bigger!
- *Social construction of meaning* – Erickson advocates that concept-based models function much more powerfully when collaborative group work is used to get different minds working together to "scaffold each other and generate new ideas and solutions" (p. 9). Such a socially-based view of pedagogy underpins most modern approaches to teaching and learning.

Principle:
Key features of effective concept-based teaching models include recognising that both facts and concepts are essential elements of curriculum, and that learning is at its most effective when organised as a collaborative activity.

Erickson provides in tabular form a summary of the differences between her three-dimensional approach (facts, skills and concepts) and a traditional two-dimensional approach (facts and skills only).

From two-dimensional instruction	To three-dimensional instruction
The goal is increased factual knowledge and skill development.	The goal is increased conceptual understanding supported by factual knowledge and skills, and the transfer of understanding across global contexts.
Teacher relies heavily on lecture to disseminate factual knowledge.	Teacher facilitates student inquiry into important interdisciplinary and

	disciplinary topics and issues using one or two key concepts as the conceptual draw.
Instruction and learning experiences focus on factual examples and definitions of concepts with assumed conceptual understanding.	Instruction and learning experiences utilize concepts along with factual content to ensure synergistic thinking. Teacher deliberately uses concepts to help students transcend the facts.
Teacher posts objectives for each lesson as required.	Teacher posts questions of different kinds (factual, conceptual, debatable) to engage interest and to facilitate synergistic thinking.
Students face the teacher in straight rows to ensure order and attention to the teacher's instruction.	Students often work in groups to facilitate shared social inquiry, collaboration, synergistic thinking and problem-solving. Students may work independently, in pairs or groups, or across global contexts using the internet or other communication tools.
Teacher verbally summarizes the learning related to the objectives at the close of the lesson.	Teacher uses inductive teaching to draw the statement of conceptual understanding from students near the end of a lesson and posts the central or suggested supporting ideas for later connections to future topics in the curriculum. Students support their understanding with accurate facts as evidence of quality synergistic thinking.
Assessments measure factual knowledge and skills.	Assessments of conceptual understanding tie back to a central (or supporting idea) by incorporating specific language from the idea in the task expectations.
Teacher focuses on covering the required curriculum.	Teacher focuses on student thinking and understanding. He/she is cognizant of each student's ability to think synergistically.

There have been some empirical studies of Erickson's recommended approach in action. The research of Sunder (2015) is particularly useful in that it focuses upon a case study of an IB school implementing a concept-based curriculum programme. Key outcomes of this research were that the teachers involved did express their preference for the broadly based curriculum that CBTL gave them, contrasting this with the more prescriptive approaches to curriculum they had previously worked with. This flexibility did, on the other hand, create its own problems: teachers identified issues to do with lack of consensus between them and their colleagues over what exactly should be in the curriculum and how this might be made coherent for their students. Having an enhanced freedom to make choices did bring with it a number of more practical problems. Sunder herself concluded her research with a mixed message: "This is certainly reason to believe that teachers see the value and purpose in being active agents in curriculum recontextualization and that teachers do value the notion of teaching for conceptual understanding. However, this, when coupled with having to choose the curriculum content and developing a coherent curriculum, has made the experience both challenging and burdensome for the teachers". (p. 156).

This focus upon the teachers who have to implement an innovative curriculum also appeared in the research of Fair (2014). This study targeted secondary teachers implementing concept-based instruction in a number of US schools and explored the supports and barriers to successful implementation. The key issue emerging was that success in implementing CBI depended crucially on the degree to which a teacher was trained and prepared for such a task. Teacher understanding clearly influenced the success of their implementation of CBI strategy, and the research reports the disappointing outcome that 5 of the 8 teachers in this study had actually abandoned a concept-based approach by the end of the research, largely due to lack of school support.

Principle:
The implementation of concept-based teaching can bring enhanced freedom to choose for teachers but this can in itself generate lack of consensus, and teachers will need careful support as they try to implement such an approach.

The key features of the concept-based instruction models discussed in the section are given in Table 1 below.

Table 1: CBTL models – key features

CBTL Model	**Key references**	**Key features**
Applebee curriculum integration model	Applebee (1996)	• Curriculum should not stress knowledge as a body of information to be mastered • Instead, sees knowledge as action, of activity in cultural practices, and traditions of discourse • Curricula not catalogues of items, collections of information, etc. • Rather, should be organised to enable students to integrate knowledge through participation in an extended conversation, and to discover interrelationships across curriculum elements.
5E Teaching model	Ampartzaki and Kalogiannakis (2015)	• Involves the use of modelling, demonstration, explanation and questioning, using 5 phases of activity, namely: • Engagement: Children encounter a topic and engage their preliminary understanding. • Exploration: Children search in a variety of sources and different ways to find answers

		or verify their initial perceptions/knowledge about the topic. • Explanation: Children develop evidence-based explanations about the issue at hand. • Elaboration: Children are challenged to apply their new knowledge to a novel situation related to the topic. • Evaluation: Children reflect on their learning and (in partnership with the teacher) assess the level of understanding they have reached.
Science-Technology-Science (STS) approach	Mbajiorgu & Ali (2003) Kapici et al (2017)	• Students try to solve problems that are relevant to their daily lives • Students become involved in resolving social issues and see science as a way of fulfilling their responsibilities as citizens • Students seek out information and use it in order to solve the problems • Students are able to follow the developments in technology and able to see the relation between scientific concepts and technological progression. • Teaching does not only take place at school but also supported with informal learning environments like science centres and science museums. • Students in science class wonder about what the future might be like. • Students are prompted to enjoy and gain experience through learning process.
Graphic organiser model	McCoy and Ketterlin-Geller (2004)	• The teacher determines the concept that is the target of instruction. • A graphic organizer is developed to illuminate this concept for the students. • Students' success in mastering the concept is measured by applying it across instances using increasingly complex critical thinking measures.
Integrated Curriculum Model	VanTassel-Baska & Wood (2010)	Students asked to: • identify examples of a concept, • organize and reflect upon it, • provide counter examples of the concept, • develop generalizations, • apply those generalizations to previous and future knowledge.
Understanding by Design	Wiggins and McTighe (2005)	• Backward design - begins with the objectives of a unit and then proceeds "backwards" to create lessons to achieve those desired goals.

		• The primary goal of UbD is student understanding: the ability to make meaning of "big ideas" and transfer their learning. • Understanding is demonstrated when students autonomously transfer their learning through authentic performance. • Teachers are coaches of understanding, not mere transmitters of content. • UbD reflects a "continuous improvement" approach. Student performance informs needed adjustments.
Erickson's model	Erickson (2012)	• Synergistic thinking – the interplay between thinking at the factual and conceptual levels. "Just knowing the definitions of concepts is not sufficient. Just knowing facts is not sufficient". Learners need both. • Transfer of knowledge and skills –facts do not transfer as they are situated in particular contexts. Knowledge can only transfer at the conceptual level as generalizations and principles are applied across contexts. • Social construction of meaning – concept-based models function much more powerfully when collaborative group work is used to get different minds working together to generate new ideas.

Research question 4: What teaching approaches and strategies appear to facilitate the development of conceptual understanding?

The paradigm shift required to teach conceptually was mentioned earlier in this review and so far we have explored this in terms of approaches to student assessment and to models for curriculum planning. Our attention now shifts to the effects of a concept-led approach on what happens inside the classroom. What does conceptual teaching look like, and what teaching approaches and strategies can facilitate it?

A focus on the 'big ideas'

According to Erickson (2002, 2007, 2008), conceptual teaching or concept-based instruction must go beyond student fact acquisition. Rather, it is about teaching the big ideas of a subject using relevant content, information or facts to support that teaching (Sim, 2016). Teachers are not required to teach ALL the factual content of a subject in conceptual teaching. They need, instead, to select and reorganise only the material they need to ensure that their students can access and learn these big ideas. There is some debate in the literature about whether conceptual teaching is best achieved through inductive teaching as pupils are guided to understand the big ideas or through direct instruction of what these ideas are (deductive teaching). There may, in fact, be a place for both approaches.

> ***Principle***:
> In concept-based teaching, teachers are not required to teach ALL the factual content of a subject but should select and reorganise only the material they need to ensure that their students can access and learn the big ideas.

The big ideas of a subject take the form of concepts and generalisations. Unlike facts which are specific examples of people, places, situations or things (Erikson, 2008), concepts are cognitive constructs devised by people to help them manage and make sense of the massive amount of information, people, places, things, events, etc. they encounter in their lives, both in and out of schools. As a species, we manage this by organising ideas into meaningful categories which share the same essential characteristics and differentiate them from non-examples (Sim, 2016). Such categorisations function as "hooks" on which people can "hang" new information. If the information does not seem to fit an existing conceptual hook well, they can either change their ideas in the hook or construct a brand new one.

> ***Principle***:
> The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects. Such categorisations function as "hooks" on which learners can "hang" new information.

Schill and Howell (2011) argue that a crucial aspect in concept-based instruction is its use of an overarching idea to provide what they term "a conceptual lens" through which students are encouraged to view the content of a particular subject. The use of such a lens enables learning to be focused, and students to think at a much deeper level about the content and its facts (Erickson 2007). Using a conceptual lens can get students to move towards thinking and using language as a practitioner would in that particular discipline (Tomlinson et al. 2002). Schill and Howell (2011) give the example of introducing the concept of change to a group of students. They firstly asked these students to work in small groups to brainstorm 30 examples of the concept of change. Next, they were asked to brainstorm 30 non-examples of change. They sorted the examples into one of four categories they had devised, although they quickly realized that some examples could fit into more than one category, which required modifications to the categories. The students were then introduced to the idea of a generalization and asked to develop three to five of these using the information they had created, analysed, and evaluated to form categories. The students struggled with this but were clearly having to think very deeply. Although Schill and Howell do not claim that the work they report could count as research, it does provide a useful case study of strategies to produce deep thinking in students. It does contrast with the approach typical in many classrooms, in which concepts are taught mostly through deductive methods, where a new idea (a theorem, a formula, a concept) is introduced before the students get to know how they are applied in examples. This takes away the opportunity for students to develop their own understanding (Tan, 2017). To teach conceptually means that the teacher acts as a facilitator to help students construct knowledge and concepts and to encourage them to make links between what they know and what they are learning.

The learning cycle

The CBTL process has been characterised as a learning cycle and involves teachers structuring their lessons to ensure inquiry-based instruction is included (Mucenski, 2004). This cycle is based upon constructivist-teaching methods, in which inquiry-based strategies are emphasized, to allow students to explore and develop concepts (Omer 2002). Research into the effectiveness of the learning cycle has been reviewed by Lawson (2001) and shown to be particularly successful in the teaching of sciences. "When the learning cycle method was implemented in the context of biological instruction it was proven effective at helping students construct concepts, and conceptual systems as well as develop more effective reasoning patterns" (Lawson, 2001, 165). The learning cycle can be divided into five basic steps.

1. The engagement phase in which students are exposed to a topic and their existing knowledge discussed (and any misconceptions revealed).
2. The exploration phase in which students explore new materials and ideas. The aim of this exploration is to raise questions, complexities, or contradictions.
3. The explanation phase in which new terms and patterns discovered during exploration are explained. After students have had new terms and patterns defined and clarified for them, the teacher designs activities in which they can apply their newly acquired knowledge.
4. The application phase in which students apply the new terms or patterns in a range of different contexts. As Lawson argues, (p.166) "Concept application is necessary to extend the range of applicability of new concepts and reasoning patterns. Without such applications, meanings may remain restricted to examples used in their introduction"
5. The final stage, evaluation, actually takes place throughout the learning cycle and student understanding is constantly monitored to ensure their accurate understanding of new concepts. (Mucenski, 2004)

Principle:
Concept-based teaching can be thought of as a learning cycle divided into five steps.

1. The engagement phase in which students are exposed to a topic and their existing knowledge discussed (and any misconceptions revealed).
2. The exploration phase in which students explore new materials and ideas. The aim of this exploration is to raise questions, complexities, or contradictions.
3. The explanation phase in which new terms and patterns discovered during exploration are explained.
4. The application phase in which students apply the new terms or patterns in a range of different contexts.
5. The evaluation phase actually takes place throughout and involves the constant monitoring of student understanding to ensure accurate understanding of new concepts.

The importance of classroom talk

Lesson structures are clearly important, but perhaps even more significant is the way in which teachers and students interact in lessons. In traditional teaching, such interaction is relatively simple – teachers dominate the exchanges, they teach from the front of the class, largely through lecture and questioning, and their questioning tends to follow a set pattern. The pattern of teacher questioning is perhaps one of the mostly widely found features of classrooms. Since its first labelling by Sinclair and Coulthard (1975), literally hundreds of research studies have confirmed that this largely consists of what are termed IRF patterns - Initiation (the teacher asks a question), Response (a student answers this), Feedback (the teacher gives feedback on the accuracy of the answer). The implications of such a dominant pattern of discourse in classrooms are, firstly, that teachers talk far more than students in almost every lesson, and that the lines of thinking are dominated by sequences the teacher has already determined. This does not seem to sit well with the notion of concept-led teaching, which will place greater emphasis on learners actively engaging with ideas and sometimes taking the lead in terms of the direction a lesson will go in (Erickson, 2012).

This does not imply that teachers should not ask questions in lessons. Given that they typically ask up to two questions every minute, up to 400 in a day, around 70,000 a year, or two to three million in the course of a career (Hastings, 2003), it would hardly be possible to change this behaviour entirely. Chang-Wathall (2016) suggests, however, that learners can be supported in developing generalisations through the use of guiding questions, which are intended to be rather different in nature to traditional teacher questions (to which most teachers already know the answer!). Guiding questions come in three forms:

- Factual questions, which focus on content that it has been identified that students need to know. These can be seen as the 'what' questions and often ask for definitions or memorised items or vocabulary. Some examples in Mathematics are:
    - What is y=mx+b?
    - What do the letters m and b stand for?
    - What is the quadratic formula?
    - What do the letters a, b, and c stand for in the quadratic formula?
- Conceptual questions, which connect this factual content with the concepts which underpin it. Often conceptual questions start with: How or why…? Some examples in Mathematics are:
    - How is a variable different from a parameter?
    - How does the concept of "mapping" explain the concept of a function?
    - How would you describe direct proportionality between two variables' means?
    - How does y = mx+b represent a translation and a transformation?
    - How do we model real life situations using functions?
- Open questions, sometimes called debatable or provocative questions, which provoke thought and discussion. Some examples in Mathematics are:
    - Were logarithms invented or discovered?
    - How well does a linear function fit all situations in real life?
    - How reliable are predictions when using models?

Questioning in classrooms is a traditionally powerful activity and some teaching has been labelled the Socratic method, after the Greek philosopher who used it to bring out the beliefs underpinning his students' assertions. It has been suggested (Tan, 2017) that teachers could profitably think in terms of Socratic questioning as a powerful tool for posing questions that provoke deep thinking in learners. This involves a process of hypothesis elimination process in that better hypotheses are found by steadily identifying and eliminating those that lead to contradictions. The teacher needs to 'pose a carefully constructed sequence of questions to students to help them improve their logical reasoning and critical thinking' (Tomlinson et al. 2002, p. 55). In a classroom, the use of the Socratic questioning technique is one way of creating a dialogue between teacher and students, in which both have a chance to clarify and verify concepts and knowledge.

Principle:
Teachers ask a great many questions in lessons but need to consider varying the types of questions, to include not just factual questions, which focus on content that students need to know, but also conceptual questions, which connect this factual content with the concepts which underpin it, and open questions, designed to provoke thought and discussion.

Macro and micro strategies for classroom interaction

According to Williams and Clement (2014), leading good discussions in the classroom is sometimes considered to be an art rather than a science. Although engaging with students in meaningful conversations about abstract and conceptually challenging concepts seems likely to be an effective way of developing their understanding of these concepts, the specific strategies that a teacher may employ to enable such conversations are not well understood. Williams and Clement attempt to draw out through their research some key characteristics of teachers who led productive discussions with their students in their science lessons. Their results indicated that a range of macro and micro strategies were used. At the macro level: the researchers used the acronym OGEM to categorise the teacher statements and questions used.

- **O**bservations. Teachers either asked for or made observations about shared experiences. Did you notice that …; Tell us what you saw when …
- **G**eneration. These asked students to generate and explanation for, or theory about, what they had seen. What do you think was happening when …; What explanation can you give for …
- **E**valuation. These questions either asked for, or provided, a judgement or critique of an explanation. Do you agree with …; Are you sure you can …
- **M**odification. These asked for or provided a possible change or modification to a theory. Maybe we could also explain it …; Does anyone see it differently?

The micro-strategies observed included such things as: Teacher provides an analogy; Teacher suggests a possible way to explain an observation.

Williams and Clement (2014) suggest that they have identified some of the features of good, dialogical teaching. Certainly what they explore is very reminiscent of the model of dialogic teaching put forward by Alexander (2017), who characterises it as:

- Collective: teachers and children address learning tasks together, whether as a group or as a whole class;
- Reciprocal: teachers and children listen to each other, share ideas and consider alternative viewpoints;
- Supportive: children articulate their ideas freely, without fear of embarrassment over 'wrong' answers; and they help each other to reach common understandings;
- Cumulative; teachers and children build on their own and each other's ideas and chain them into coherent lines of thinking and enquiry;
- Purposeful: teachers plan and steer classroom talk with specific educational goals in view.

Alexander's dialogic teaching approach has been extensively investigated in primary classrooms, with the most recent study (Alexander et al, 2017) finding that pupils experiencing a dialogic teaching intervention had made on average two months more progress in their learning than a comparable control group.

Principle:
Dialogic teaching has been shown to lead to enhanced learning and is characterised by certain features of classroom interaction, namely:

- Collective: teachers and children address learning tasks together, whether as a group or as a whole class;
- Reciprocal: teachers and children listen to each other, share ideas and consider alternative viewpoints;
- Supportive: children articulate their ideas freely, without fear of embarrassment over 'wrong' answers; and they help each other to reach common understandings;
- Cumulative; teachers and children build on their own and each other's' ideas and chain them into coherent lines of thinking and enquiry;
- Purposeful: teachers plan and steer classroom talk with specific educational goals in view.

Hwang (2016) has suggested a number of questioning strategies which she terms "inductive strategies" and which fit well with a dialogic approach to teaching conceptually. These include:

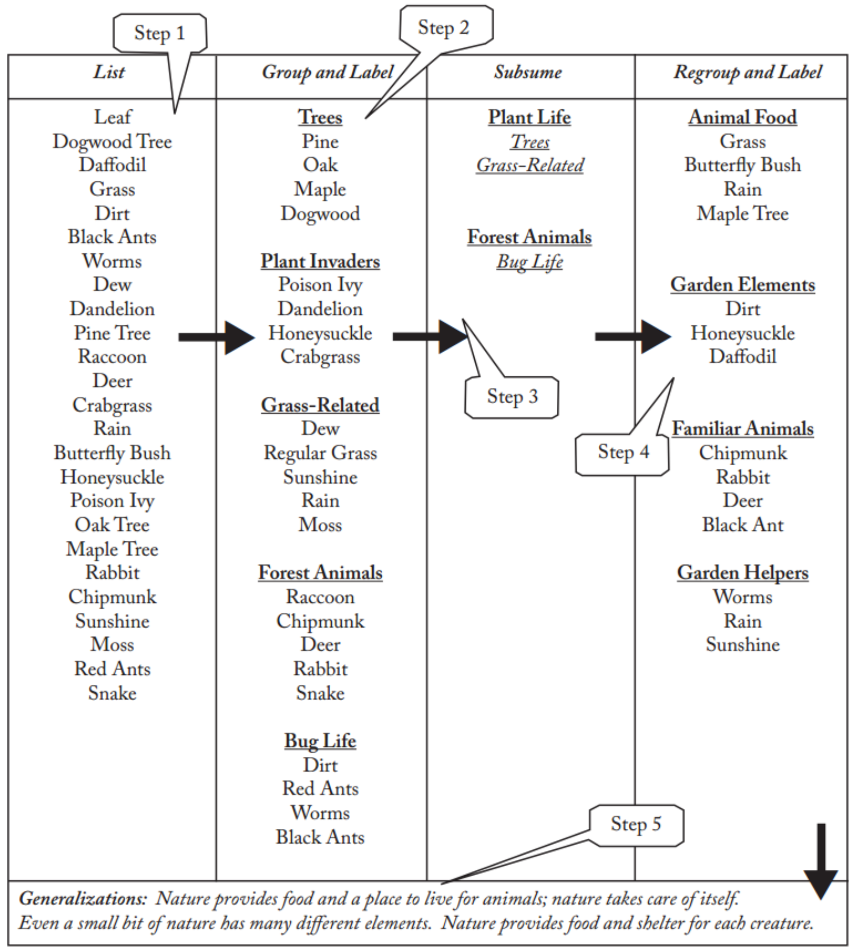
1. The Concept-Attainment Strategy (Reinhartz & Van Cleaf, 1986). The teacher presents students with a minimum of five sets of examples and non-examples in alternate fashion and tells the class that the examples have something in common, asking them to infer the critical attributes in the examples and guess what the concept would be. Afterwards, students are asked to provide their own examples and non-examples.
2. The Taba Generalisation Strategy (Taba, 1967) Students are asked to examine the data in an inquiry and select which is relevant to the inquiry questions. Next, they try to relate each item of data to each other and explain why something happened or why the relationship exists. They then consider the implications of the findings and make inferences, which encourages them to generalise beyond the information and concept.

Hwang (2016) also refers to another “Taba Strategy” (Taba, 1967) in which the teacher begins by asking students to brainstorm a list of things linked to a topic, and then to categorise these things into sub-groups. They have to identify the critical attributes for the subgroups and think of a name for their subgroups. They will then need to justify their groupings and state a definition and description for each. Gallagher (2012) exemplifies this strategy in a sequence of teaching ‘steps’:

Step 1	List	Gather a list of about 25 items that can be placed together under one category.
Step 2	Group and Label	Group and label the items from Step 1
Step 3	Subsume	Cross-categorize items and/or create a hierarchy of ideas using the items and groups from Step 2
Step 4	Regroup	Set aside groups and labels from Step 2, and create completely new groups using the items from Step 1
Step 5	Generalize	Make broad but relevant statements about the nature of the items on the list based on insights gathered during Steps 1-4

Gallagher illustrates this by an example from a teaching unit with 10 year olds on the natural world.

PROGRESSION OF A CONCEPT DEVELOPMENT LESSON
Purpose of Discussion: *To extend and clarify students’ understanding of interactions among elements of nature*
Grade Level: *Elementary*
Source of Background Information: *Personal experience*
First Focusing Question: *What are examples of nature in your backyard?*



Active learning pedagogies

In a more general sense, active-learning pedagogies have been shown to improve student conceptual understanding (Hake, 1998) Active learning means more than engaging and motivating students to complete classroom exercises. Rather, activities should be designed around learning outcomes, promote student reflection, and get students to think about what they are learning (Brooks et al, 2014). A research review by Prince (2004) found that there was broad support for the core elements of active, collaborative, cooperative and problem-based learning, while Dong (2005) confirms that what he refers to as 'action learning' has also proved to be very beneficial at undergraduate level. Active, or action, learning also links very strongly with Problem-Based Learning (PBL). This, according to Veronese et al (2013) has three main learning goals:
(1) to promote deep content learning (Belland et al. 2009);
(2) to promote problem-solving skills, determine relevant resources to help analyse the problem and develop a solution to address the problem (Hmelo-Silver 2004)
(3) to promote self-directed learning (Hmelo et al. 1997).

Principle: Active learning pedagogies have been shown to improve student conceptual understanding and involve students actively reflecting upon what they are learning.

Concept maps as learning tools

We earlier reviewed (see p. 41) the role of concept maps in the assessment of conceptual understanding. Concept mapping is also a tool that has been demonstrated repeatedly to have a positive impact on the quality of student learning (e.g., Nesbit & Adesope, 2006; Ritchhart, Turner, & Hadar, 2009; Kinchin (2014). Concept maps appear to allow students to link new knowledge with existing knowledge and promote a problem-solving approach to student thinking. Veronese et al (2013) have also demonstrated that the use of concept maps can enhance examination performance at undergraduate level.

In fact, concept mapping has been widely used in various courses at a range of levels (Hwang et al, 2014). For example, Kim and Olaciregui (2008) designed a learning activity in which students accessed a concept map-based information display to review a science portfolio; Liu, Chen, and Chang (2010) used concept maps as an aid to improve English as a Foreign Language students' English reading comprehension; and, Adesope and Nesbit (2013) used concept mapping as a way of guiding narrative reading. Most studies have shown the effectiveness of concept mapping in helping students organize and understand the target concepts. The results of Nair and Narayanasamy's (2017) study support the research findings of Novak (2005) (and many other studies by the same researcher), which showed that the use of concept maps helped students to understand and organize Science concepts in a more meaningful manner and enhanced their understanding. Their findings also showed that students can organize complex concepts graphically by using concept maps.

There is evidence that concept mapping is more effective than other constructive activities (e.g. writing summaries and outlines) (Nesbit and Adesope 2006) and ICT-based strategies using learning outcomes (e.g. free recall and transfer) in science (Adesope et al. 2016). A meta-analysis of related evidence confirmed that concept mapping may benefit learners across a broad range of educational levels, subject areas and settings (Berkeley et al. 2010). Morfidi et al (2018) recently reported on their study of the effectiveness of digital text-based and multimedia concept mapping among poor readers using with information texts. The results clearly indicated that both concept mapping approaches contributed significantly to poor readers' understanding, whereas traditional teaching did not yield a significant change in the reading scores of a control group.

In order to maximise the benefits accruing from the use of concept mapping as a teaching tool, Kinchin (2014, p.46) has suggested that the following key points be borne in mind:

- Concept mapping should be used in compatible curriculum settings that reflect the constructivist underpinnings of the tool. If the teaching and the assessment regimes within a curriculum are intent on transmitting fixed information from teacher to student, then the potential utility of concept mapping is lessened.

- Concept mapping should be used as a learning tool, “directing” the search for information, not “ending” it. If an expert concept map represents the answer to be memorised by students, then the learning will not be meaningful.
- Teachers should have clear instructional objectives for the use of concept mapping that need to be conveyed to students. It is not helpful to students to simply see concept mapping as another activity within the teaching scheme unless there is a clear aim in doing it. Teachers need to be clear about the benefits to students, and share this with them.
- The degree of freedom allowed to students in a concept mapping activity should be justified and explicit. Students may be presented with a blank sheet of paper or with a list of concepts to link. Either approach has validity, depending what it is that the teacher is hoping to achieve.
- Concept mapping should be combined with other learning strategies such as collaborative learning, dialogue, and feedback. Concept mapping is most effective as a learning tool when combined with complementary activities to enhance the learning environment.

Principle:
Concept mapping is also a tool that has been demonstrated repeatedly to have a positive impact on the quality of student learning.

Outcome 2: Analysis of the Documents

Research Questions

The research questions which were the focus of this part of this study were as follows:

Research question 2: What are the existing approaches and understanding of CBTL embedded in relevant curriculum documentation in each IB programme?
a) How does each IB programme develop conceptual understanding?
b) To what extent does the role and integration of concepts align within and across the IB programmes?

Our approach towards answering these questions involved a number of steps, more fully described in the material which follows. These were:

1. The principles arising from the literature review were extracted.
2. Using an inductive analysis, these principles were grouped thematically.
3. The curriculum documentation for each of the four IB programmes was studied, using the audit tool.
4. Comparative analyses were carried out of the fit with the principles a) across the IB programmes and b) across a range of IB subjects.

Developing an audit tool

Thirty-three key principles were derived from the literature review and used to audit a range of IB programmes and subjects. These principles were considered 'key' in the sense that they were endorsed by a consensus of research literature and, importantly, fitted with other key principles also emerging, sometimes from widely differing research studies. As a step towards a conceptual framework against which to conduct the audit, these principles were organized into 5 themes, derived from a 'bottom-up' analysis of the principles themselves. These themes were as follows:

1. Principles concerning the nature of concepts
2. Principles concerning the development of these concepts in learners at different stages
3. Principles concerning the key features of concept-based teaching
4. Principles concerning the nature of effective classroom interaction in concept-based teaching
5. Principles concerning the assessment of developing conceptual understanding

The organization of the principles into the five themes is given in Table 2 below.

Table 2: Themed principles emerging from the literature review

Theme	Principle
The nature of concepts	1 Concepts are mental representations of categories of objects, events, or other entities.
	2 Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings",

	"essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.
	3 Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. It is important that some emphasis be given in teaching to the more over-arching concepts rather than trying to cover lots of material in a superficial way.
	4 Concepts are tools for organising experience but also for extending the effects of such experience beyond the here and now.
	5 A threshold concept changes the way in which a student views a subject. Such a concept is likely to be challenging to the learner but, once acquired, is irreversible and transformative.
Concept development	6 Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts by deliberately introducing learners to a wider range of scientific/academic concepts that they probably would not develop simply through personal life experiences.
	7 Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.
	8 Crucial to the development of scientific/academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.
	9 Young children are capable of abstract thinking, provided that the context of such thinking makes human sense to them.
	10 Theories help learners to identify those features that are relevant to a concept and influence how concepts are stored in memory. Therefore, even quite young children need to be encouraged to theorise (predict) about aspects of the world.
	11 Learners need to be encouraged to develop their concepts in an area through both *assimilation* (adding new information to existing mental structures) and *accommodation* (reworking existing conceptual structures to take account of new information).
	12 Students learn best when: 1. concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general; 2. concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned; 3. the difficulty of a task meets student capabilities.
Concept-based teaching – key features	13 Effective concept-based teaching processes involve asking students to: 1) identify examples of a concept, 2) organize and reflect upon this, 3) provide counter examples of the concept, 4) develop generalizations, 5) apply those generalizations to previous and future knowledge.
	14 Concept-based teaching is conceived as a form of inductive teaching in which learners are guided to understand the big ideas rather than being taught directly about these ideas.
	15 Curriculum should not stress knowledge as a body of information to be mastered, but rather as the joining in with traditions of discourse through which students are enculturated to the values of academic disciplines, and it should be organised to enable students to

	integrate knowledge and discover interrelationships across all elements.
	16 In concept-based teaching, teachers are not required to teach ALL the factual content of a subject but should select and reorganise only the material they need to ensure that their students can access and learn the big ideas.
	17 The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects. Such categorisations function as "hooks" on which learners can "hang" new information.
	18 Approaches in which students are encouraged to apply their understandings to real life problems are more successful than traditional textbook-based approaches.
	19 Backward design in curriculum planning begins with the objectives of a unit or course—what students are expected to learn and be able to do—and then proceeds "backwards" to create lessons to achieve those desired goals.
	20 Key features of effective concept-based teaching models include recognising that both facts and concepts are essential elements of curriculum, and that learning is at its most effective when organised as a collaborative activity.
	21 Concept-based teaching can be thought of as a learning cycle divided into five steps. 1. The engagement phase in which students are exposed to a topic and their existing knowledge discussed (and any misconceptions revealed). 2. The exploration phase in which students explore new materials and ideas. The aim of this exploration is to raise questions, complexities, or contradictions. 3. The explanation phase in which new terms and patterns discovered during exploration are explained. 4. The application phase in which students apply the new terms or patterns in a range of different contexts. 5. The evaluation phase actually takes place throughout and involves the constant monitoring of student understanding to ensure accurate understanding of new concepts.
	22 The implementation of concept-based teaching can bring enhanced freedom to choose for teachers but this can in itself generate lack of consensus, and teachers will need careful support as they try to implement such an approach.
Classroom interaction in concept-based teaching	23 Teachers ask a great many questions in lessons but need to consider varying the types of questions, to include not just factual questions, which focus on content that students need to know, but also conceptual questions, which connect this factual content with the concepts which underpin it, and open questions, designed to provoke thought and discussion.
	24 Dialogic teaching has been shown to lead to enhanced learning and is characterised by certain features of classroom interaction, namely: • Collective: teachers and children address learning tasks together, whether as a group or as a whole class; • Reciprocal: teachers and children listen to each other, share ideas and consider alternative viewpoints;

	• Supportive: children articulate their ideas freely, without fear of embarrassment over 'wrong' answers; and they help each other to reach common understandings; • Cumulative; teachers and children build on their own and each other's' ideas and chain them into coherent lines of thinking and enquiry; • Purposeful: teachers plan and steer classroom talk with specific educational goals in view.
	25 Active learning pedagogies have been shown to improve student conceptual understanding and involve students actively reflecting upon what they are learning.
	26 Concept mapping is also a tool that has been demonstrated repeatedly to have a positive impact on the quality of student learning.
Assessing conceptual understanding	27 Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.
	28 A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.
	29 Talking to learners, whether through structured interviews, guided questions, or encouraging thinking aloud is one of the most effective ways of accessing their thought processes.
	30 Asking students to express their ideas graphically can also provide a powerful window into their thought processes and understandings. This can involve the use of graphic organisers or concept maps.
	31 Learners can be asked to represent their on-going understandings in more structured ways through devices such as KWL grids and word clouds.
	32 Teachers can detect changes in learners' conceptual understandings by looking for key indicators, namely when: • the level of their understanding and use of abstract concepts increases; • they make connections between multiple concepts; • they apply and transfer their understandings to more complex and distant contexts as well as to those that are familiar; • they take responsible actions and make informed decisions that are based on their new understandings; • they begin to understand that concepts can have different interpretations.
	33 One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.

The conceptual framework developed as above was then used to analyse and compare of a range of IB programmes and subjects. The matching of principles to materials will now be reported

Key analyses

The following analyses were carried out using the audit tool as just described:

1. Generic comparisons between the four programmes.

2. An analysis of several individual subject areas across the four programmes. The subject areas focused upon were Drama/Theatre Studies, Language acquisition, Mathematics, Science/Chemistry, and Social studies/History.

Across programme analysis

Following the interrogation of a range of IB documents using the principles gleaned from the literature, a comparative table was drawn up, focusing upon a) how the principles were met, or not met, in the From Principles into Practice (FPiP) documents, and b) whether there were differences in the matching of these principles across the four IB programmes. To show clearly the process of analysis, this table is provided in Appendix 1, where it is hoped it can act as an exemplar of the process we used to derive the statement below of issues arising.

We will preface this statement with a visual summary of ways in which the four programmes currently meet the principles arising from the literature review.

A summary of the audit of programme documentation against research-based principles
Key

🟢	This principle fits with the material in the documentation
🟡	This principle partially fits with the material in the documentation
🔴	This principle does not fit with the material in the documentation
⚫	We could find no evidence regarding the fit of this principle

Theme: The nature of concepts		**PYP**	**MYP**	**DP**	**CP**
Principles from the literature	1 Concepts are mental representations of categories of objects, events, or other entities.	🟢	🟢	🟢	🟡
	2 Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings", "essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.	🟢	🟢	🟢	🟡
	3 Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. It is important that some emphasis be given in teaching to the more over-arching concepts rather than trying to cover lots of material in a superficial way.	🟢	🟡	🟡	⚫
	4 Concepts are tools for organising experience but also for extending the effects of such experience beyond the here and now.	🟡	🟡	🟡	⚫
	5 A threshold concept changes the way in which a student views a subject. Such a concept is likely to be challenging to the learner	⚫	⚫	⚫	⚫

	but, once acquired, is irreversible and transformative.				

Theme: Concept development		**PYP**	**MYP**	**DP**	**CP**
Principles from the literature	6 Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts by deliberately introducing learners to a wider range of scientific/academic concepts that they probably would not develop simply through personal life experiences.				
	7 Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.				
	8 Crucial to the development of scientific/ academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.				
	9 Young children are capable of abstract thinking, provided that the context of such thinking makes human sense to them.				
	10 Theories help learners to identify those features that are relevant to a concept and influence how concepts are stored in memory. Therefore, even quite young children need to be encouraged to theorise (predict) about aspects of the world.				
	11 Learners need to be encouraged to develop their concepts in an area through both *assimilation* (adding new information to existing mental structures) and *accommodation* (reworking existing conceptual structures to take account of new information).				
	12 Students learn best when: a) concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general; b) concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned; c) the difficulty of a task meets student capabilities.				

Theme: Concept-based teaching – key features		**PYP**	**MYP**	**DP**	**CP**
Principles from the literature	13 Effective concept-based teaching processes involve asking students to: a) identify examples of a concept, b) organize and reflect upon this, c) provide counter examples, d) develop generalizations, e) apply those generalizations to previous and future knowledge.				

	14 Concept-based teaching is conceived as a form of inductive teaching in which learners are guided to understand the big ideas rather than being taught directly about these ideas.	⚫	⚫	⚫	⚫
	15 Curriculum should not stress knowledge as a body of information to be mastered, but rather as the joining in with traditions of discourse through which students are enculturated to the values of academic disciplines.	⚫	⚫	⚫	⚫
	16 In concept-based teaching, teachers are not required to teach ALL the factual content of a subject but should select and reorganise only the material they need to ensure that their students can access and learn the big ideas.	⚫	🔴	🔴	⚫
	17 The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects.	🟢	🟡	🟢	🟡
	18 Approaches in which students are encouraged to apply their understandings to real life problems are more successful than traditional textbook-based approaches.	⚫	⚫	⚫	⚫
	19 Backward design in curriculum planning begins with the objectives of a unit or course—what students are expected to learn and be able to do—and then proceeds "backwards" to create lessons to achieve those desired goals.	⚫	⚫	⚫	⚫
	20 Key features of effective concept-based teaching models include recognising that both facts and concepts are essential elements of curriculum, and that learning is at its most effective when organised as a collaborative activity.	🟢	🟡	🟡	🟡
	21 Concept-based teaching can be thought of as a learning cycle divided into five steps: engagement, exploration, explanation, application, evaluation.	⚫	⚫	⚫	⚫
	22 The implementation of concept-based teaching can bring enhanced freedom to choose for teachers but this can in itself generate lack of consensus, and teachers will need careful support as they try to implement such an approach.	⚫	⚫	⚫	⚫

Theme: Classroom interaction in concept-based teaching		**PYP**	**MYP**	**DP**	**CP**
	24 Dialogic teaching has been shown to lead to enhanced learning and is characterised by certain features of classroom interaction, namely it is Collective, Reciprocal, Supportive, Cumulative, Purposeful.	⚫	⚫	⚫	⚫
	25 Active learning pedagogies have been shown to improve student conceptual	🟡	🟢	⚫	⚫

	understanding and involve students actively reflecting upon what they are learning.				
	26 Concept mapping is also a tool that has been demonstrated repeatedly to have a positive impact on the quality of student learning.	⚫	⚫	⚫	⚫
Principles from the literature	27 Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.	🟡	⚫	⚫	⚫
	28 A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.	🟢	🟡	🟡	⚫
	29 Talking to learners, whether through structured interviews, guided questions, or encouraging thinking aloud is one of the most effective ways of accessing their thought processes.	⚫	⚫	⚫	⚫
	30 Asking students to express their ideas graphically can also provide a powerful window into their thought processes and understandings. This can involve the use of graphic organisers or concept maps.	⚫	⚫	⚫	⚫
	31 Learners can be asked to represent their on-going understandings in more structured ways through devices such as KWL grids and word clouds.	⚫	⚫	⚫	⚫
	32 Teachers can detect changes in learners' conceptual understandings by looking for key indicators.	⚫	⚫	⚫	⚫
	33 One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.	🟢	🟡	🟡	⚫

Definitions of concepts

There is, on the face of it, general agreement across the programmes about the nature of concepts. In PYP FPiP, the definition is that "Concepts are powerful, broad and abstract organizing ideas that may be transdisciplinary or subject-based". In the MYP and DP equivalent documents this becomes "A concept is a 'big idea'—a principle or notion that is enduring, the significance of which goes beyond particular origins, subject matter, or place in time". The idea of a concept as a 'notion that is enduring' is a little strange. The research literature generally refers to 'enduring understandings', so it is the representation of an idea in a learner's mind which endures, rather than the idea itself. Ideas, of course, only have existence when in the mind of a human.

There may, of course, be some debate over the mapping of concepts to subject matter. For the PYP; concepts can be transdisciplinary OR subject-based, a choice which seems to be eschewed by both the MYP and DP definitions, where it is claimed that a concept is something with significance going BEYOND subject matter. This contrasts with a general model of curriculum which usually becomes more subject discipline focused as it relates to older students. The PYP document is rightly suspicious about the relevance of 'subject' to young children's learning – "While a student's prior knowledge may align with the subjects identified by the PYP, young students do not experience the world through these lenses." Transition across MYP to DP level is, of course, marked by the increasing importance of subject boundaries. The insistence on concepts as going beyond these barriers may be seen partially as an attempted corrective to this shifting emphasis.

Key and related concepts

The PYP and MYP documents rely quite heavily on the distinction made between key and related concepts, a distinction which is not, as far as we can tell, derived from the literature. There is a suggestion that the terms key and related concepts are used a little differently in PYP to in MYP. In the PYP FPiP document it states that "Key concepts provide a lens for conceptual understandings within a transdisciplinary unit of inquiry; related concepts provide a lens for conceptual understandings within a specific subject" (p.79). But later (p.81) the document states that "Related concepts explore key concepts in greater detail and also add depth to the programme", suggesting that the across subject/within subject distinction is not quite what is meant. As an example of this, for the key concept *Causation*, examples of related concepts given include *Consequences* and *Impact*. It is not clear that either of these are necessary subject-focused and both could potentially function as key concepts in their own rights. The distinction is much firmer in the MYP. In the MYP FPiP document, key concepts are defined as "powerful, abstract ideas that have many dimensions and definitions. They have important interconnections and overlapping concerns. Key concepts engage students in higher-order thinking, helping them to connect facts and topics with more complex conceptual understanding" (p.15), whereas related concepts "are grounded in specific subjects and disciplines, and .. are useful for exploring key concepts in greater detail (and) may arise from the subject matter of a unit" (p.15). Both key and related concepts are prescribed in MYP subjects, suggesting a rather 'tighter' definition of curriculum than in the PYP.

The distinction does not, as we have said, derive from the literature in either case. The literature does tell us (Principle 3) that "Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts", a distinction commonly made by researchers and theorists. The implication usually taken from this distinction is that high level concepts are more important for learners to grasp than are low level concepts, and, indeed, that a curriculum should deliberately plan to cover high level concepts rather than simply trying to cover lots of low level material. We recognise that this fits the spirit of the IB documentation but wonder if the cross discipline / within discipline definition of key and related concepts may not convey this adequately.

Generalisation and transfer

Two principles arising from the literature review concerned the vexed topic of transfer of learning. Research into learning strongly suggests that concepts learned in one area of study may not transfer to other areas unless this transfer is deliberately promoted and taught. Research also suggests that if generalizability across subject areas / situations is a sought after learning outcome then the arousing of a learner's conscious awareness of what they are learning is crucial.

The issue of transfer of learning is certainly mentioned in the IB documentation, yet in a relatively uncritical way. In the PYP FPiP, for example, "Transfer skills" (sic) is listed as one of the sub-skills (under Thinking Skills) in the Approaches to Learning skills map on p.61. Student activities to develop what is then referred to as "Information Transfer" are listed on p.66:

- Use memory techniques to develop long-term memory.
- Inquire in different contexts to gain different perspectives.
- Make connections between units of inquiry and between subjects.
- Transfer conceptual understandings across transdisciplinary themes and subjects.
- Combine knowledge, conceptual understandings and skills to create
- products or solutions.
- Apply skills and knowledge in unfamiliar situations or outside of school.
- Help others develop conceptual understandings and skills. (p.66)

In the MYP equivalent document, we are told that "Effective teaching and learning in context helps students and teachers to … build up the skills and experience necessary to transfer learning from one context to another (p.17-18). The transfer of skills is one of the key Approaches to Learning (ATL) skills, elaborated in detail in Appendix 1 of this guide. It is summarized by the question: "How can students transfer skills and knowledge across disciplines and subject groups?" and a number of strategies are suggested, under the heading of "Using skills and knowledge in multiple contexts.

- Use effective learning strategies in subject groups and disciplines
- Apply skills and knowledge in unfamiliar situations
- Inquire in different contexts to gain a different perspective
- Compare conceptual understanding across multiple subject groups and disciplines
- Make connections between subject groups and disciplines
- Combine knowledge, understanding and skills to create products or solutions
- Transfer current knowledge to learning of new technologies
- Change the context of an inquiry to gain different perspectives" (p.114)

This is a similar but not identical list to that given in the PYP Guide.

In the DP FPiP, the claim is made that: "DP courses help learners to construct meaning as they become increasingly competent critical and creative thinkers, able to transfer knowledge and take responsibility for their own learning" (p.70). This claim is also extended to the CP: "CP students engage with a challenging programme of study that genuinely interests them while gaining transferable and lifelong skills in applied knowledge, critical thinking, communication, and cross-cultural engagement" (p.16).

The emphasis upon transfer of learning is thus consistent across the IB programmes, and the achievement of this is cited as a major benefit arising from a concept-based approach. Yet the research informs us that such transfer is only likely to happen if there is a strong deliberateness in the teaching, and if learners are made explicitly awareness of their own learning and its potential in other fields of knowledge. Such deliberateness and awareness may be implied in the IB programmes, but they are not explicitly stressed in the way which the research suggests they need to be.

It should be remembered also that the research we have cited in the literature review takes a relatively 'soft' approach to transfer of learning. There is plenty of other research which suggests that transfer is much more problematic that might at first appear. McKeough et al (1995), for example, conclude that, "Researchers have been more successful in showing how people fail to transfer learning than they have been in producing it, and teachers and employers alike bemoan students' inability to use what they have learned." (p. vii). Dixon and Brown (2012) attribute this to school being unable to provide sufficient authentic problem-solving activities to adequately prepare students for real-world problems. While Lave and Wenger (1991) analyse the way in which situation is so bound up with learning that what is learnt can hardly be separated from it.

Situated cognition is a theory which emphasizes that people's knowledge is constructed within and linked to the activity, context, and culture in which it was learned (Brown et al, 1989; Aydede & Robbins, 2009). Learning is social and not isolated, as people learn while interacting with each other through shared activities and through language, as they discuss, share knowledge, and problem-solve during these tasks. For example, while language learners can study a dictionary to increase their vocabulary, this often solitary work only teaches basic parts of learning a language, which learners may quickly forget unless they make the effort to retain the information gleaned in their memories. When language learners talk with someone who is a native speaker of the language, however, they learn important aspects of how words are used in the native speaker's home culture and how the words are used in everyday social interactions. The evidence is that such socially-embedded knowledge persists much longer and can be used in different situations. Thus, knowledge cannot be separated from the context or situation in which it was acquired. What is meant by situated is that learning is connected to a culture, place, activity, or social situation. In other words, learning does not happen in isolation from other people or our environment. We learn in and from specific places and interactions, and usually that learning is so bound up with the situation in which it was learnt that it cannot simply be applied in other contexts.

A more recent, and even more radical take on this notion of learning as situated in a context is the theory of embodied cognition (Shapiro, 2011). This involves the claim that the brain, while important, is not the only resource we have available to us to learn. Instead, learning is seen as emerging from the real-time interaction between a nervous system in a body with particular capabilities and an environment that offers opportunities for behaviour and information about those opportunities. The reason this is quite a radical claim is that it changes the job we see the brain as doing; instead of having to represent knowledge about the world and use that knowledge to simply output commands, the brain is now a part of a broader system that critically involves perception and action as well.

The actual solution an organism comes up with for a given task includes all these elements.

A good example of embodied cognition is the activity of learning to write. This is a complex activity, involving a combination of motor skills and cognitive planning. A typical approach to teaching it is to focus on the motor aspects first (the handwriting) and, when these are soundly grasped by the learner, move on to teaching the cognitive aspects. Recent research in this area (Medwell & Wray, 2008) suggests, however, that successful writing in fact consists of an integration of motor movements with several stores of knowledge (knowledge of a topic, knowledge of an audience, knowledge of rhetoric, etc.). The thought in writing is not separate from the physical aspect – it is bound up with it, embodied.

What research in this area suggests is that the process of transfer of learning from one context to another is not as simple as it might seem. In recent years, the low-road/high-road theory on transfer of learning, developed by Salomon & Perkins (1994), has proven to be fruitful. Low-road transfer refers to developing some knowledge/skill to a high level of automaticity. It usually requires a great deal of practice in varying settings. Tying one's shoe laces, using a keyboard, steering a car, and single-digit arithmetic facts are examples of areas in which such automaticity can be achieved and is useful. High-road transfer involves: cognitive understanding; purposeful and conscious analysis; mindfulness; and application of strategies that cut across disciplines. In high-road transfer, there is deliberate mindful abstraction of an idea that can transfer, and then conscious and deliberate application of the idea when faced by a problem where the idea may be useful. We assume that in the IB documentation, this high road transfer is what is being aimed at, and suggest that more attention needs to be given to deliberateness in focusing learners on new contexts in which their learning might be applied, and on ensuring learners are sufficiently aware of the possibilities of application to other contexts.

Authenticity

One of the principles drawn from the literature stated that: "Students learn best when: concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned". The issue of authenticity in learning is either stated or implied throughout the IB documentation, yet the stress upon it does seem to diminish as we move through the age ranges. A count was carried out of the number of times the words "authentic" or "authenticity" were mentioned in the PYP FPiP document and we found almost 60 uses of these words. Authenticity was linked to:

- student agency – "When teachers support student agency, they … foster authenticity for students to explore their interests by giving them open-ended tasks" (p.5)
- the PYP Exhibition, one of the purposes of which is stated as – "to provide students with an opportunity to demonstrate the attributes of the learner profile in authentic contexts" (p.34).
- trans-disciplinarity, the themes of which are said to "allow for authentic embeddedness of subject areas" (p.48).
- effective assessment, described as "Authentic: It supports making connections to the real world to promote student engagement" (p.97).

Such heavy emphasis upon the idea of authenticity clearly indicates the major role perceived for this in the programme.

In the MYP equivalent document, the words "authentic" or "authenticity" were mentioned 26 times, but with at least 10 of these mentions being in reference to student honesty in assessment. In the DP there were only 12 such mentions with most being concerned with student honesty in assessment.

This raises the question of whether the idea of authenticity, in terms of learning material, contexts for learning, assessment of learning, etc. is genuinely seen as decreasing in importance as students get older.

Big ideas and schemas

A principle arising from the literature is expressed as: "The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects. Such categorisations function as "hooks" on which learners can "hang" new information." This principle comes from theories of cognitive development and learning which suggest that learners construct mental maps of the world (schemas) which, through assimilation of new ideas, can form the cognitive architecture which is built upon to develop and extend understanding. Another of the principles is that "Learners need to be encouraged to develop their concepts in an area through both assimilation (adding new information to existing mental structures) and accommodation (reworking existing conceptual structures to take account of new information)", referring to the mechanisms through which new learning is achieved.

This schema theory has become such a commonplace idea in cognitive psychology, being initially popularised through the work of Piaget, that it was a little surprising that it was not until the DP FPiP document that there was mention of it. This document quotes Anderson and Krathwohl (2001) to the effect that: "Students understand when they build connections between the 'new' knowledge to be gained and their prior knowledge. More specifically, the incoming knowledge is integrated with existing schemas and cognitive frameworks. Since concepts are the building blocks for these schemas and frameworks, conceptual knowledge provides a basis for understanding." (p.71).

It does seem that, in the PYP FPiP, this body of theory is implicit, however. Statements such as: "Students co-construct beliefs and mental models about how the world works based on their experiences and prior learning. They integrate new knowledge with their existing knowledge and apply these understandings in a variety of new contexts. They learn to recognize patterns and see the connections between discrete examples to strengthen conceptual understandings" (p.79), can only have been written by someone who understood schema theory, even if the name itself is not mentioned. It might be useful to try to embed such a conception of learning into the MYP FPiP as well. It does not conflict with the notion of concept-based learning and an understanding of it may, in fact, enhance this underpinning theoretical framework.

Gaps in the application of principles to planning documents

Many of the principles arising from the literature review do appear to fit with material in the FPiP documents. There are, however, some large gaps where it was difficult to find evidence that these principles informed the IB approach. Looking at the nature of these gaps, it is clear that they mostly involve principles which focus upon actual classroom action (rather than underpinning curriculum structures). One of the research sub-questions guiding our literature search and analysis was: "What teaching approaches and strategies are associated with CBTL and/or effectively facilitate the development of conceptual understanding?" We answered this through a thorough review of the research literature deriving principles such as:

- Effective concept-based teaching processes involve asking students to:
    1) identify examples of a concept,
    2) organize and reflect upon this,
    3) provide counter examples of the concept,
    4) develop generalizations,
    5) apply those generalizations to previous and future knowledge.

- Concept-based teaching can be thought of as a learning cycle divided into five steps, which are more thoroughly described in the literature review (p.50).
    1) The engagement phase.
    2) The exploration phase.
    3) The explanation phase.
    4) The application phase.
    5) The evaluation phase.

- Teachers ask a great many questions in lessons but need to consider varying the types of questions, to include not just factual questions ('what' questions), which focus on content that students need to know, but also conceptual questions ('how' or 'why' questions), which connect this factual content with the concepts which underpin it, and open questions, designed to provoke thought and discussion. Examples of questions of these types have been given in the literature review (p. 55) of this report.

- Dialogic teaching has been shown to lead to enhanced learning and is characterised by certain features of classroom interaction. These are fully described in the literature review (p. 57).

- Active learning pedagogies have been shown to improve student conceptual understanding and involve students actively reflecting upon what they are learning.

It has proved difficult to find any evidence from the IB documents we have studied that the above principles do underpin CBTL in the IB, although from our knowledge of IB programmes, it seems unlikely that they do not. This might suggest a gap in terms of the documentation, rather than recommended pedagogic practices. Perhaps there is a need for further documentation, and maybe Continuing Professional Development, to focus on pedagogy in order to help ensure that the sound theoretical underpinnings given in the programme guides might best be translated into effective classroom action.

Individual subject analyses

We will preface these analyses with a visual summary of ways in which the five subjects we focused upon currently meet the principles arising from the literature review.

A summary of the audit of subject documentation against research-based principles

Key

🟢	This principle fits with the material in the documentation
🟡	This principle partially fits with the material in the documentation
🔴	This principle does not fit with the material in the documentation
⚫	We could find no evidence regarding the fit of this principle

Theme: The nature of concepts		**Theatre studies**	**Lang-uages**	**Maths**	**Science**	**History**
Principles from the literature	1 Concepts are mental representations of categories of objects, events, or other entities.	🟢	🟢	🟡	🟢	🟢
	2 Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings", "essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.	🟢	🟢	🟡	🟢	🟢
	3 Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. It is important that some emphasis be given in teaching to the more over-arching concepts rather than trying to cover lots of material in a superficial way.	🟡	🟡	🟡	🟡	🟡
	4 Concepts are tools for organising experience but also for extending the effects of such experience beyond the here and now.	⚫	🟡	⚫	🟡	🟡
	5 A threshold concept changes the way in which a student views a subject. Such a concept is likely to be challenging to the learner but, once acquired, is irreversible and transformative.	⚫	⚫	⚫	⚫	⚫

Theme: Concept development		Theatre studies	Lang-uages	Maths	Science	History
Principles from the literature	6. Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts by deliberately introducing learners to a wider range of scientific/academic concepts that they probably would not develop simply through personal life experiences.	●	●	●	●	●
	7. Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.	●	●	●	●	●
	8. Crucial to the development of scientific/ academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.	●	●	●	●	●
	9. Young children are capable of abstract thinking, provided that the context of such thinking makes human sense to them.	●	●	●	●	●
	10, Theories help learners to identify those features that are relevant to a concept and influence how concepts are stored in memory. Therefore, even quite young children need to be encouraged to theorise (predict) about aspects of the world.	●	●	●	●	●
	11. Learners need to be encouraged to develop their concepts in an area through both *assimilation* (adding new information to existing mental structures) and *accommodation* (reworking existing conceptual structures to take account of new information).	●	●	●	●	●
	12. Students learn best when: a) concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general; b) concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned; c) the difficulty of a task meets student capabilities.	●	●	●	●	●

Theme: Concept based teaching – key features		Theatre studies	Lang-uages	Maths	Science	History
Principles from the literature	13. Effective concept-based teaching processes involve asking students to: a) identify examples of a concept, b) organize and reflect upon this, c) provide counter examples, d) develop generalizations, apply those generalizations to previous and future knowledge.	⚫	⚫	⚫	⚫	⚫
	14. Concept-based teaching is conceived as a form of inductive teaching in which learners are guided to understand the big ideas rather than being taught directly about these ideas.	⚫	⚫	⚫	⚫	⚫
	15. Curriculum should not stress knowledge as a body of information to be mastered, but rather as the joining in with traditions of discourse through which students are enculturated to the values of academic disciplines.	⚫	⚫	🟡	🟡	🟡
	16. In concept-based teaching, teachers are not required to teach ALL the factual content of a subject but should select and reorganise only the material they need to ensure that their students can access and learn the big ideas.	⚫	🟡	⚫	🟡	🟡
	17. The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects.	🟢	🟡	⚫	🟡	🟡
	18. Approaches in which students are encouraged to apply their understandings to real life problems are more successful than traditional textbook-based approaches.	⚫	🟢	🟢	🟡	⚫
	19. Backward design in curriculum planning begins with the objectives of a unit or course—what students are expected to learn and be able to do—and then proceeds "backwards" to create lessons to achieve those desired goals.	⚫	⚫	⚫	⚫	⚫
	20. Key features of effective concept-based teaching models include recognising that both facts and concepts are essential elements	🟢	🟢	⚫	🟢	🟢

	of curriculum, and that learning is at its most effective when organised as a collaborative activity.					
	21. Concept-based teaching can be thought of as a learning cycle divided into five steps: engagement, exploration, explanation, application, evaluation.	⚫	🟢	🟡	🟡	🟡
	22. The implementation of concept-based teaching can bring enhanced freedom to choose for teachers but this can in itself generate lack of consensus, and teachers will need careful support as they try to implement such an approach.	⚫	⚫	⚫	⚫	⚫

Theme: Classroom interaction in concept-based teaching		**Theatre studies**	**Lang-uages**	**Maths**	**Science**	**History**
Principles from the literature	23. Teachers ask a great many questions in lessons but need to consider varying the types of questions, to include not just factual questions, which focus on content that students need to know, but also conceptual questions, which connect this factual content with the concepts which underpin it, and open questions, designed to provoke thought and discussion.	🟡	🟡	⚫	🟡	🟡
	24. Dialogic teaching has been shown to lead to enhanced learning and is characterised by certain features of classroom interaction, namely it is Collective, Reciprocal, Supportive, Cumulative, Purposeful.	⚫	⚫	⚫	⚫	⚫
	25. Active learning pedagogies have been shown to improve student conceptual understanding and involve students actively reflecting upon what they are learning.	🟢	🟢	🟢	🟢	🟢
	26. Concept mapping is also a tool that has been demonstrated repeatedly to have a positive impact on the quality of student learning.	⚫	⚫	⚫	⚫	⚫

Theme: Assessing conceptual understanding		**Theatre studies**	**Lang-uages**	**Maths**	**Science**	**History**
Principles from the literature	27. Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.	🟡	⚫	⚫	⚫	⚫

	28. A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.	●	●	●	●	●
	29. Talking to learners, whether through structured interviews, guided questions, or encouraging thinking aloud is one of the most effective ways of accessing their thought processes.	●	●	●	●	●
	30. Asking students to express their ideas graphically can also provide a powerful window into their thought processes and understandings. This can involve the use of graphic organisers or concept maps.	●	●	●	●	●
	31. Learners can be asked to represent their on-going understandings in more structured ways through devices such as KWL grids and word clouds.	●	●	●	●	●
	32. Teachers can detect changes in learners' conceptual understandings by looking for key indicators.	●	●	●	●	●
	33. One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.	●	●	●	●	●

Drama/Theatre Studies

Following the interrogation of a range of IB documents using the principles gleaned from the literature, a comparative table was drawn up, focusing upon a) how the principles were met, or not met, in the documents relevant to Theatre Studies, and b) whether there were differences in the matching of these principles across the four IB programmes. To show clearly the process of analysis, this table is provided in Appendix 2, where it is hoped it can act as an exemplar of the process we used to derive the following statement concerning issues arising. It should be understood that, because we examined generic documents (e.g. FPiP documents) as well as more subject-specific documents, several of the points raised have generic reference as well as being specific to Theatre Studies.

Concepts: definitions and place in theatre studies

In terms of definitions of concepts, there is a slight gap between the PYP on the one hand and the MYP/DP on the other. The MYP Arts guide defines a concept as a "big idea"— "a principle or notion that is enduring, the significance of which goes beyond particular origins, subject matter, or place in time" (page 22), a definition echoed in the DP FPiP document. In the PYP FPiP document, however, concepts are defined as "powerful, broad and abstract organizing ideas that may be transdisciplinary or subject-based" (p. 79). It sounds inconsistent to suggest that concepts can, at the same time, go beyond particular subject matter AND be subject-based. The difference here echoes the Piagetian distinction between concrete and formal cognitive operations (See page 25) and links with the Principle derived from the literature (page 28) that "Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting." It may well be possible for concepts at MYP and DP levels to go beyond particular subject boundaries but this may only happen if such generalisation is deliberately taught. The MYP does make a deliberate attempt to foster interdisciplinary teaching and learning, trying to build a "connected curriculum". "Connectedness" is also an important theme in the DP programme, with the Theory of Knowledge course a key element in this.

The main issue in terms of drama at PYP level concerns a potentially confusing slippage in terminology, and key terms are sometimes not clearly enough defined. For example, in the PYP Arts scope and sequence document (2009) it is stated that "Students will demonstrate knowledge and understanding of the concepts, methods and elements of … drama …, including using specialized language" (p.2). The assumption from this is that "concepts, methods and elements" are different things, yet the document does not say how they are different. Later, in presenting the structure of the arts in terms of continua for responding and creating, the document defines what it means by learning outcomes ("observable behaviours or actions that will indicate to teachers how students are constructing, creating and sharing meaning through arts" p. 6) but there is no comparable definition of 'conceptual understandings'. For example, in the continuum for Responding phase 3, one conceptual understanding is given as "People explore issues, beliefs and values through art" and a learning outcome for Drama at the same phase is given as "consider the composition of an audience when preparing an effective formal and/or informal presentation". It is not clear why one of these is a conceptual understanding but the other is not.

This does become a little clearer in the Creating continuum (p. 17) as the learning outcomes tend to be phrased in terms of a series of action verbs – share, use, make use of, express, etc. The conceptual understandings, on the other hand, tend to be expressed in verbs of a different type – "We can enjoy", "We are receptive to", "Our experiences can inspire us". This verb type shift suggests more enduring understandings than a simple set of actions. However, there is some likely confusion in these conceptual understanding statements in that some refer directly to generalities which students are expected to come to understand – e.g. "The art is a means of communication and expression"; "There is a relationship between the artist and the audience". Whereas others refer to the feelings and thought processes which students are expected to develop – e.g. "We enjoy and experience different forms of arts"; "We reflect and act on the responses to our creative work". It is not obvious how these latter statements should be taken as conceptual understandings.

As we discussed earlier (p. 76) the PYP and MYP documentation relies quite heavily on the distinction made between key and related concepts. This distinction is not, as we pointed out, derived from the literature, and it appears to be used differently in PYP to in MYP. On the one hand there is a view that key concepts refer to understandings within a transdisciplinary unit of inquiry, with related concepts focusing on understandings within a specific subject. Elsewhere, however (PYP FPiP, p.81), related concepts are designed to "explore key concepts in greater detail and also add depth to the programme".

In the case of Theatre Studies, the cross discipline / within discipline definition of key and related concepts is adopted for use in the Arts at MYP level. The MYP Arts Guide defines key concepts as "big ideas that are both relevant within and across disciplines and subjects" (p. 22) and lists the key concepts contributed by the arts as aesthetics, change, communication and identity. Related concepts are defined as "grounded in specific disciplines and are useful for exploring key concepts in greater detail" (p. 24). A list of these related concepts is provided in Table 2 of the document, and given below:

Related concepts in arts			
Visual arts			
Audience	Boundaries	Composition	Expression
Genre	Innovation	Interpretation	Narrative
Presentation	Representation	Style	Visual culture
Performing arts			
Audience	Boundaries	Composition	Expression
Genre	Innovation	Interpretation	Narrative
Play	Presentation	Role	Structure

This list is slightly problematic in two ways.

Firstly, there is considerable overlap between the lists for visual arts and performing arts, which makes the claim that these are 'grounded in specific disciplines' harder to sustain. It is also true that several of these concepts will also be found in other disciplines. Sometimes, of course, they will mean rather different things. Composition in writing is different from composition in drama, although arguably not conceptually but simply in mode. But concepts such as innovation and interpretation are certainly cross-disciplinary in their meaning. This suggests that a definition of the above concepts as being 'grounded in specific disciplines' is rather hard to sustain.

Approaches to teaching in theatre studies

The three Arts-focused documents (PYP Arts scope and sequence, MYP Arts Guide and DP Theatre Guide) each place a good deal of emphasis upon inquiry-led learning, with rather less explicit reference to concept-based teaching. In the PYP, the recommendation is that, "Wherever possible, arts should be taught through the units of inquiry and should support students' inquiries" (p.2), even though it is recognized that this may not always be possible. The MYP Arts Guide reinforces this by its recommendation that "teachers and students use statements of inquiry to help them identify factual, conceptual and debatable inquiry questions. Inquiry questions give direction to teaching and learning, and they help to organize and sequence learning experiences" (p. 26). It seems that, as with the PYP, conceptual learning and inquiry-led learning are seen to go hand in hand.

This emphasis loses some force at DP level. The DP Theatre Guide refers to the six approaches to teaching, i.e. teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment (p. 4) and is imbued throughout with an emphasis upon inquiry as a basis for learning. But CBTL is scarcely referred to in this document, almost certainly as a result of the increasing emphasis upon disciplinarity at this level.

Approaches to assessment

In the PYP, assessment of student progress is organised around the two strands of Responding and Creating, for each of which the requisite conceptual understandings are spelt out in a set of learning continuums, across four phases of development (PYP Arts scope and sequence). It is not entirely clear how these learning continuums develop, however. To take one example, in the continuum for Creating, at Phase 1 five descriptor statements are listed, against which a teacher can judge a child's progress. For Phase 2, there are four descriptor statements, for Phase 3 three and for Phase 4 three. There are no obvious themes of development running across the phases. Which makes the implicit model of conceptual development seem rather haphazard.

In the MYP the assessment criteria are described using a familiar statement-based structure. In the MYP Arts Guide, the end of year 5 level descriptors for Knowledge and Understanding, for example, centre around three statements:

"The student:
i. demonstrates … knowledge and understanding of the art form studied, including concepts, processes, and … use of subject-specific terminology
ii. demonstrates … understanding of the role of the art form in original or displaced contexts
iii. demonstrates … use of acquired knowledge to purposefully inform artistic decisions in the process of creating artwork". (p.48)

Progression is indicated by the use of either of the adjectives *limited*, *adequate*, *substantial* or *excellent* being used in place of the … in each of these statements.

Such an approach to developing level descriptors is widely used in curriculum planning. Its potential weakness is, of course, whether teachers using the descriptors all share an understanding of the precise meanings of the adjectives limited, adequate, substantial or excellent. One way of avoiding the problem here would be to develop a broader set of exemplars showing how teachers have applied the scheme.

In the DP assessment descriptors play a similar role, although the adjectives used here are limited, underdeveloped, good and excellent. Again, it is not entirely clear how progression in conceptual development can be gauged using such a framework. There are almost certainly exemplars available showing applications of this framework.

Languages

After following a similar process to that described above for Theatre Studies (the interrogation of a range of IB documents using the principles gleaned from the literature, drawing up a table to show comparisons across the programmes, focusing upon issues arising), the following issues arose in the area of Languages (Languages (PYP), Language Acquisition (MYP), and Language B (DP)).

The IB's vision and commitment to all young people learning an additional language as part of the curriculum from the age of 7 in order to develop their linguistic skills and intercultural understanding is an important and welcome commitment.

Concepts: definitions and place in Languages

There were several places in the Languages documentation where a common and consistent approach to terminology in relation to concepts, conceptual understandings, conceptual themes, 'big ideas', and related concepts seemed less secure than it could have been. Terminology is used interchangeably in courses which can be confusing. For example, in DP Language B - "identities, experiences, human ingenuity, social organization and sharing the planet" are referred to interchangeably in the DP Language B documentation as 'themes' - 'prescribed conceptual themes', 'concepts' and 'Big Ideas'. Reference is also made to 'conceptual understandings' of audience, context, purpose, meaning and variation.

This suggests the need for a common and consistent approach to terminology within and across courses and programmes, and, perhaps, the development of a glossary in all programmes to clarify factual knowledge, procedural knowledge, disciplinary knowledge, and conceptual knowledge

Approaches to teaching in Languages

Each IB language course adopts a different and distinct approach to CBTL. The PYP foregrounds concept-based and transdisciplinary approaches which aim to bring 'relevance, authenticity and connection' to student learning'. The Transdisciplinary learning in the PYP document refers to learning that is not confined within the boundaries of traditional subjects but is supported and enriched by them' (PYP FPiP). A crucial idea relates to the desirability of students being encouraged to 'transfer their conceptual understanding to new situations' (Language Scope and Sequence). The means of achieving this is through a programme of inquiry which is seen as providing an authentic context for learners to develop and use their additional language. Transfer and inquiry are thus key ideas in PYP language work.

In the MYP the focus changes somewhat to an interdisciplinary context. 'Teachers use key concepts from their own subject group(s)—as well as key concepts from other subject groups—to plan disciplinary and interdisciplinary units of work (MYP: FPiP). Teachers and schools are encouraged to plan units which provide opportunities for 'interdisciplinary teaching and learning' and there is a requirement that at least one collaboratively planned interdisciplinary unit should be incorporated for each year of the programme. The thorny issue of transferability is not highlighted, although inquiry does still dominate as a crucial idea. 'The MYP promotes inquiry in language acquisition by developing conceptual understanding within global contexts' (Language Acquisition: Subject Brief).

The DP Language Acquisition programme incorporates two modern language courses - Language ab initio and Language B that are offered in a number of languages. These courses are designed 'to provide students with the necessary skills and intercultural understanding to enable them to communicate successfully in an environment where the language studied is spoken' (DP Language B Guide). Inquiry and transferability are not particularly stressed, although the guide makes explicit and frequent references to the important relationship between the development of language skills and conceptual understandings. Such an increased focus upon disciplinary demands is, of course, natural at this level, although the definition being used here of conceptual understandings seems limited to "an understanding of why and how people use language to communicate" (Language B Guide), that is, a focus on some aspects of culture. It is interesting to notice that the CP documentation takes this idea of the conceptual bases underpinning language use somewhat further, with language study aiming to provide "students with the opportunity to develop insights into the features, processes and craft of language and the concept of culture, and to realize that there are diverse ways of living, behaving and viewing the world'. (CP FPiP).

At present there are no specific key concepts which are foregrounded across all of the language acquisition courses although 'related concepts' or 'conceptual understandings' such as audience, context and purpose feature implicitly or explicitly in all courses – reflecting perhaps a link to the seminal work of Halliday (1977) on functional linguistics (the study of the relationship between language and its functions in social settings).

In addition to streamlining the course documents as suggested above, perhaps the most helpful addition to support policy into practice/enactment would be to develop a comprehensive range of Unit Planners (transdisciplinary-interdisciplinary or disciplinary) in collaboration with teachers to provide exemplification of a CBTL approach. This would assist with the integration of curriculum, pedagogy and assessment.

Given the title of this 'subject' consideration could also be given to providing some common background and vision in relation to the IB approach to 'language acquisition' across the language courses/programmes. If the language acquisition courses draw upon Halliday's work and a text-based, genre-based approach, then it would be helpful to provide some background for language teachers and perhaps also consider some of the emerging research in the field of Second Language Acquisition - for example the DFG Transdisciplinary Framework for SLA (Douglas Fir Group, 2016).

Approaches to assessment

It would be useful to establish a common curriculum design across all Language B/lLanguage acquisition courses using clear and consistent language to facilitate better teacher understanding, greater consistency and better alignment of curriculum, pedagogy and assessment and to secure the integration and embedding of CBTL. Linked to this would be the development of a common overarching framework to map the development of conceptual understandings and language competencies, expectations, goals, language continuums and assessment criteria and to embed and make conceptual understandings explicit in all language acquisition. These conceptual understandings need to be made explicit in assessment objectives and frameworks, building on the conceptual understandings outlined in the PYP and further in the Global Proficiency Table (MYP) and assessment criteria and descriptors in DP Language B.

It was not always clear in the documentation which concepts and conceptual understandings were central and explicit in assessment criteria in each of the additional language courses in each of the programmes. At present the multiple layers could potentially be confusing for teachers and detract from continuity. One suggestion would be to provide an overview and a common approach to presenting the key concepts, related concepts and progression in conceptual understandings – so that teachers and learners have a better understanding of expectations in relation to increasing the breadth, depth and complexity of understanding when revisiting concepts or working with new and different concepts.

There is a need for some overarching key concepts across all additional language/language acquisition courses such as those in the MYP - communication, connections, creativity and culture - and ensure that these concepts reflect the overarching aims of learning an additional language and go beyond an emphasis on 'how language works'. It may be helpful here to consider the recent developments in relation to the mapping of intercultural communication by the NCSSFL-ACTFL (National Council of State Supervisors for Languages – American Council for the Teaching of Foreign Languages) (2017) and the CEFR (Common European Framework of Reference for Languages) (2018) work on plurilingual/ pluricultural competences.

Mathematics

After following a similar process to that described above for other subjects (the interrogation of a range of IB documents using the principles gleaned from the literature, drawing up a table to show comparisons across the programmes, focusing upon issues arising), the following issues arose in the area of Mathematics.

Concepts: definitions and place in Mathematics

In most of the Mathematics documentation, the term 'concept' is used differently than elsewhere in IB material. Unsurprisingly perhaps, the term is usually linked with the word 'mathematical'. This generally refers to knowledge in this subject and is often partnered with the term 'skills'. The term 'Mathematical concepts and skills' refers to more or less complex bodies of knowledge and how to use them. Thus, the mathematical concept of multiplication and the skill of performing it accurately. There is not the sense of concepts as overarching, categorising ideas that is found in other subjects. Mathematical concepts are, of course, abstractions and can still be described as 'enduring understandings', yet the sense remains that that CBTL means something different in Mathematics.

The concepts of *form*, *logic* and *relationships* are described as key concepts, using the familiar key/related concepts terminology. These can serve as overarching concepts in similar ways to in other subjects, yet the documentation does not put these key concepts at the core of mathematics teaching. The section in the MYP Mathematics Guide where the idea of key and related concepts is discussed (as far as we can tell, the only place in the IB Mathematics materials where this is done) is placed firmly within the main section on Teaching and Learning through Inquiry, suggesting that Inquiry pedagogy is the main point of this section. The document states, "Teachers and students develop a statement of inquiry and use inquiry questions to explore the subject. Through their inquiry, students develop specific interdisciplinary and disciplinary approaches to learning skills" (p.18). The following section explains the key concepts of form, logic and relationships, but the bulk of this section is devoted to the provision of guidance for planning and implementing inquiry-based teaching units. The sense is that these key concepts are described because every subject has them, not because they are essential to the conception of mathematics teaching underpinning these materials.

It is nevertheless the case that throughout the programmes it is the commonality in approaches which is clear, rather than differences between them. In both the PYP and the MYP, it is seen as important that learners acquire mathematical understanding by constructing their own meaning through increasing levels of abstraction, starting with an exploration of their own personal experiences, understandings and knowledge. Additionally, it is fundamental to the philosophy of both programmes that, since it is to be used in real-life situations, mathematics needs to be taught in relevant, realistic contexts, rather than by attempting to impart a fixed body of knowledge.

Teaching and learning experiences in both the PYP and MYP challenge students to be curious, ask questions and explore and interact with the environment physically, socially and intellectually. Through engaging in this process, students are able to construct meaning about mathematics concepts, transfer this meaning to symbols and apply mathematical understanding in familiar and unfamiliar situations.

Approaches to teaching in Mathematics

There is a heavy emphasis in all the IB Mathematics materials examined upon an inquiry approach to student learning. This begins with the PYP, which is built around the idea of student inquiry. The Mathematics Scope and Sequence document sums this up: "Learners construct meaning based on their previous experiences and understanding, and by reflecting upon their interactions with objects and ideas. Therefore, involving learners in an active learning process, where they are provided with possibilities to interact with manipulatives and to engage in conversations with others, is paramount to this stage of learning mathematics". Such an active view of learning continues right through to the DP, where the DP Mathematics HL Guide explicitly states: "The IB Learner Profile encourages learning by experimentation, questioning and discovery. In the IB classroom, students should generally learn mathematics by being active participants in learning activities rather than recipients of instruction. Teachers should therefore provide students with opportunities to learn through mathematical inquiry" (p.11). It is probably true to say that this emphasis upon inquiry-based learning is more powerful in the Mathematics documents than is the emphasis upon CBTL. It is expressed in the MYP Mathematics Guide as: "The MYP structures sustained inquiry in mathematics by developing conceptual understanding in global contexts. Teachers and students develop a statement of inquiry and use inquiry questions to explore the subject". (p.18) This is followed through in terms of student assessment by requiring an element of student enquiry. "A task that does not allow students to select a problem-solving technique is too guided and should result in students earning a maximum achievement level of 6 (for years 1 and 2) and a maximum achievement level of 4 (for year 3 and up)" (p. 9).

The inquiry-based approach which is stressed in the Mathematics materials is strongly linked to a model of learning which foregrounds "authentic real life situations". Objective D in the Progression of Learning (MYP Mathematics Guide, p.11) sets out the learning outcomes as:

- identify relevant elements of authentic real-life situations
- select appropriate mathematical strategies when solving authentic real-life situations
- apply the selected mathematical strategies successfully to reach a solution
- justify the degree of accuracy of a solution
- justify whether a solution makes sense in the context of the authentic real-life situation.

Approaches to assessment

The mathematics materials are informed by several views of progression in understanding. At PYP level this is expressed in terms of students "understanding of the underlying concepts before being asked to transfer this meaning into symbols" (PYP Mathematics Scope and Sequence, p.3) The gap between this understanding and its resulting employment of symbols may stretch across phases of learning, intended to allow students sufficient time and opportunity to develop their understanding of a concept before being rushed into the recording of the mathematics associated with this. This separation between the development of understanding and the use of symbols to record mathematical meanings is also seen in the PYP learning outcomes for Mathematics, which state that: "The learning outcomes have been written to reflect the stages a learner goes through when developing conceptual understanding in mathematics—constructing meaning, transferring meaning into symbols and applying with understanding" (p.3).

In the MYP Mathematics Guide, there is a suggestion of a conceptual progression in terms of Knowing and Understanding when the document states that:

"This (knowledge and understanding) objective assesses the extent to which students can select and apply mathematics to solve problems in both familiar and unfamiliar situations in a variety of contexts. In order to reach the aims of mathematics, students should be able to:

i. select appropriate mathematics when solving problems in both familiar and unfamiliar situations
ii. apply the selected mathematics successfully when solving problems
iii. solve problems correctly in a variety of contexts." (p.8)

This does not actually mean that these steps are progressive, though. In the level descriptors for Knowing and Understanding (p.37), progression from Level 1-2 through to 7-8 is marked only by a change in the nature of the problems the student should be able to solve. At level 1-2 these are described as 'simple problems' in 'familiar situations', developing by level 7-8 to 'challenging problems' in 'familiar and unfamiliar situations'. Thus the change in terms of progression applies only to the nature of the problems students are able to tackle, from simple to more complex to challenging.

In terms of assessment approaches, although, inevitably with publicly examined courses such as the MYP and the DP, there is some presence of the traditional examination form of summative assessment in Mathematics, even at DP level there is some element of more student-centred assessment. The internally assessed component in the Mathematics DP course is a mathematical exploration, defined as a short report written by the student based on a topic chosen by him or her, and focusing on the mathematics of that area. This places some emphasis not just on student knowledge in the subject, but also on the student communicating in ways appropriate to the subject (including formulae, diagrams, graphs etc.). Such an inclusion clearly supports the inquiry-based philosophy which is so central to Mathematics development in all IB programmes.

In the PYP we see the usual approach to the measurement of progression through the use of Learning continuums. In this case for Data Handling, Measurement, Shape and Space, Pattern and Function, and Number, each with sets of statements exemplifying progress in four phases of development. As with other subjects, however, it is sometimes not obvious what the strands of development are across each continuum. As an example, the conceptual understandings for Phase 1 in number are given as:

- Numbers are a naming system.
- Numbers can be used in many ways for different purposes in the real world.
- Numbers are connected to each other through a variety of relationships.
- Making connections between our experiences with number can help us to develop number sense.

Of these, the fourth seems quite different to the rest in terms of a conceptual understanding of Maths – it surely relates to an awareness of themselves as learners. The statements for Phases 2 to 4 in Number do actually seem to suggest a continuum of learning but they do not relate to the statements in Phase 1. As the assessment of student progress in Mathematics at PYP is managed entirely through formative assessment, it seems important that statement continua such as these are clear and unambiguous.

Science

Again, after following a similar process to that described above for other subjects (the interrogation of a range of IB documents using the principles gleaned from the literature, drawing up a table to show comparisons across the programmes, focusing upon issues arising), the following issues arose in the area of Science.

Concepts: definitions and place in Science

From the sample units of inquiry made available to us (e.g. http://xmltwo.ibo.org/publications/PYP/p_0_pypxx_mon_1112_1/files/sample6.1_en.pdf), science is very much at the heart of PYP teaching: pedagogical approaches are described to provoke students' thinking, experience and development around the concepts of function and connection. There is a blend of teacher-led activities and student explorations to address the detailed research skills and development of the Learner Profile.

The MYP Sciences Guide, (p. 19) specifies the key concepts as change, relationship and systems. This is elaborated by considering the different sciences and tabulating 'related concepts' (p. 21). The distinction made in IB documentation, especially in the MYP materials, between key and related concepts remains a problematic one. We could find no published research justification for this and there must be some possibility that teachers using these materials will find the distinction a fairly random, and hence unhelpful, one. For example, in the MYP Sciences Guide (p.20-21) there seems no obvious reason why form is denoted as a key MYP concept, whereas function is relegated to a related concept in biology. Both form and function are listed as key concepts in the PYP FPiP (p.80). We feel that this idea needs some further explanation and justification.

The organisation of the syllabus in the DP Science course is much clearer. It is arranged by topic where 'essential ideas' and 'core concepts' are unpacked in sections to address the 'nature of science', 'understandings' and 'applications and skills', etc. (DP Chemistry Guide, p. 23 onwards). There are then the added value IB aspects such as International-Mindedness, Theory of Knowledge, etc. in the right-hand column. This is a very useful way of showing that many of these aspects can be taught in an integrated, holistic way.

Approaches to teaching in Science

The PYP Science Scope and Sequence document begins with a very clear statement of teaching philosophy. "It is recognized that teaching and learning science as a subject, while necessary, is not sufficient. Of equal importance is the need to learn science in context, exploring content relevant to students, and transcending the boundaries of the traditional subject area" (p. 1). This implies an approach largely through inquiry, which the IB PYP documents virtually all subscribe to. This is not intended to signify a loose, 'let's find out about' approach, but rather, "a highly defined, focused, in-depth programme of inquiry".

The implication running through the MYP is also that inquiry is central to science teaching and learning, underpinning the units of inquiry. The MYP Sciences Guide is rather light on pedagogy, however, with the guidance basically being limited to: "Teachers and students develop a statement of inquiry and use inquiry questions to explore the subject" (p. 19). It would be very challenging for each student to undertake an open-ended investigation on their own without support, experience and a structure, and teachers might have expected rather more in terms of support for developing an appropriate pedagogy.

This is especially the case as "In every year of MYP sciences, all students must independently complete a scientific investigation that is assessed against criterion B (inquiring and designing) and criterion C (processing and evaluating)" (p. 17). The purpose of this requirement is to ensure that students carry out one complete laboratory-based investigation (from initial design to final evaluation) in every year of the programme. Students need to develop independent hypotheses and methods to investigate an appropriately open-ended problem identified in collaboration with their teacher. Students can share equipment, and teachers can provide feedback to ensure sufficient data can be collected. It may be appropriate, particularly in the earlier years of the programme, for students to collaborate and share data, but each student should process data and evaluate results independently. Practicals (laboratory experiments) led entirely by the teacher are not seen sufficiently open-ended, and therefore do not meet this requirement.

At the DP level, there is similar encouragement in the documentation towards adopting a non-traditional approach to teaching. "It is important that students are involved in an inquiry-based practical programme that allows for the development of scientific inquiry. It is not enough for students just to be able to follow directions and to simply replicate a given experimental procedure; they must be provided with the opportunities for genuine inquiry" (DP Chemistry Guide, p. 21). The role of direct instruction is not discussed at all in the Chemistry Guide, although it is unlikely that many teachers would let the students entirely take the lead in their DP Science work.

It does seem that the inquiry-led philosophy of Science teaching is consistent throughout the IB programmes. Our suspicion is that many teachers, at all levels, might welcome more guidance on the integration of more direct instructional methods into the inquiry experience.

The PYP documentation (PYP FPiP) strongly reflects a philosophy of the classroom being a collaborative centre, which attunes well with the principle emerging from the literature that learning is at its most effective when organised as a collaborative activity. There are very few pages of the FPiP on which the word 'collaborative' does not appear! Paired and group work is clearly described and rationalised.

The document is clear about the limited use of direct teaching of the whole class, although citing Audet's (2005) description of it as "careful prompts at strategic times" – a description that very few teachers and educationalists would dispute.

The MYP Sciences Guide states: "Teachers and students develop a statement of inquiry and use inquiry questions to explore the subject. Through their inquiry, students develop specific interdisciplinary and disciplinary approaches to learning skills." (p. 19) Examples provided in the MYP document include factual questions What do cells look like?), conceptual questions (How is the universe structured?) and debatable questions (Who should have the power to modify and control genetic material?). These are not supposed to represent any difficult gradient in terms of inquiry questions. Nevertheless, there is the feeling that the example factual questions are a good deal easier to answer than the example conceptual and debatable questions.

In comparison with other DP subject guides, the DP Science Subject Guides contain a long section on the nature of science, ranging from sections on What is Science, to Scientific Literacy., and concluding with an impressively complex flowchart entitled How Science Works, which is, perhaps, more aesthetic than informative

Similar to virtually all the IB programmes, the DP in Sciences is wedded to the notion of teaching/learning as an inquiry process. The actual realisation of inquiry (structure, open-ended etc.) seems to be of less importance than the assumption that inquiry of any sort is clearly beneficial, effective and efficient in teaching and learning. It is worth bearing in mind that there is some recent evidence about effective teaching which suggests a stronger role for direct teaching than we may previously have thought:
"Many current curriculum recommendations … promote student-led and inquiry-based approaches with substantial ambiguity in instructional practices. The strong pattern of results presented in this article, appearing across all subject matters, student populations, settings, and age levels, should, at the least, imply a need for serious examination and reconsideration of these recommendations. It is clear that students make sense of and interpret the information that they are given—but their learning is enhanced only when the information presented is explicit, logically organized, and clearly sequenced. To do anything less shirks the responsibility of effective instruction." (Stockard, et al, 2018). A more extensive discussion of this issue is probably beyond the scope of the current research, yet, as educators, we always have the responsibility to reflect on appropriate, best evidenced approaches to teaching and learning for greater equality and equity.

Approaches to assessment

The philosophy underpinning assessment in the PYP is that this should allow and be based around the opportunity to reflect with the student and suggest examples such as 'transcripts of play experiences and inquiries, children's reflections, annotated images, graphic and 3D media samples, peer and self-assessment'. To highlight developments in understanding and knowledge. This philosophy is basically expounded in a long section in the PYP FPiP document, although it is not dwelt upon in the PYP Science Scope and Sequence document.

Samples are provided to exemplify the range of different assessment approaches. For example, Sample 8 (http://xmltwo.ibo.org/publications/PYP/p_0_pypxx_mon_1305_1/samples/sample08_en) shows the use of a variety of observations, discussions and analyses to show children's changing (evolving) understanding over time. Other examples in the sample bank show clearly how assessment involves teacher and student self-assessment and reflection and how the assessments made can be used to inform students and parents and also assist teacher reflection/planning. Within this wealth of material, it is unfortunate that such a discredited concept as 'Learning Styles' receives such prominence. (http://xmltwo.ibo.org/publications/PYP/p_0_pypxx_mon_1305_1/samples/sample04_en).

At MYP level, there are four objectives, elaborated by strands in MYP science, to be addressed at least twice in each year of the MYP:

A. Knowing and Understanding, (tests or exams assess this objective);
B. Inquiring and designing, (teachers must provide an open-ended problem for students to investigate);
C. Processing and Evaluating (collect, transform and analyse data);
D. Reflecting on the impacts of science (students need to be aware of the work of others, reflect on implications of using science, such as moral, social, economic, etc.).
Each of these objectives has a strong CBTL link.

The assessment objectives for chemistry at DP level reflect those parts of the aims that will be formally assessed either internally or externally. These assessments centre upon the nature of science. It is the intention of these courses that students are able to fulfil the assessment objectives as listed earlier, viz:
1. Demonstrate knowledge and understanding;
2. Apply;
3. Formulate, analyse and evaluate;
4. Demonstrate the appropriate research, experimental, and personal skills necessary to carry out insightful and ethical investigations. (DP Chemistry Guide, p. 19).

Practical work, or other assessment is assessed internally, moderated externally and forms part of the students' overall grade. The criteria for internal assessment are very fully elaborated for the assessment of practical work, with multiple indicators within each criterion: personal engagement, exploration, analysis, evaluation, and communication.

There are three written examination papers, which vary in length depending on the paper and whether the subject is studied at HL or SL. These are very focused on content, ideas and concepts and will be familiar to and understood by teachers of Chemistry.

The DP Science Guides spell out the assessment objectives for biology, chemistry and physics, according to which students should:

1. Demonstrate knowledge and understanding of:
    a. facts, concepts, and terminology
    b. methodologies and techniques
    c. communicating scientific information.
2. Apply:
    a. facts, concepts, and terminology
    b. methodologies and techniques
    c. methods of communicating scientific information.
3. Formulate, analyse and evaluate:
    a. hypotheses, research questions and predictions
    b. methodologies and techniques
    c. primary and secondary data
    d. scientific explanations.
4. Demonstrate the appropriate research, experimental, and personal skills necessary to carry out insightful and ethical investigations.

These objectives echo the configuration in the MYP Sciences Guide (p. 10), where learning outcomes are listed as:

A. Knowledge and understanding
B. Inquiring and designing
C. Processing and evaluating
D. Reflecting on the impacts of science

(On a tiny point of consistency, it might be good to change outcome A to Knowing and Understanding, so as to keep the present participle pattern here. We note that this is the nomenclature adopted in the MYP Individuals and Society document.)

In both these cases, only one of the four assessment objectives focuses on knowledge of facts and concepts, the remainder being more focused upon the skills and processes of science.

Social Studies/History

Finally, in this section, a similar process was applied to a range of IB documents focussing on History, and the following issues were noted.

Concepts: definitions and place in History

In PYP FPiP, concepts are seen as 'big ideas' that go across traditional subject boundaries. "A concept is a 'big idea'—a principle or notion that is enduring and is not constrained by a particular origin, subject matter or place in time" (p.79). This approach, within the PYP programme, has a lot to recommend it and allies itself with the underpinning philosophy of the IB programmes.

The use of related concepts helps to break down some of the 'big ideas' and enables possible links to national and other syllabus requirements and must be useful for teachers in curriculum and lesson planning. An observation would be that some of these concepts seem to be just as big or bigger than the key concepts. Reviewing the related concepts associated with *Responsibility* – Rights, Citizenship, Values, Justice – suggests that these are all huge areas and will need a number of layers for students on the PYP programme. This is not a 'size-matters' question but there is a need to think about how pupils might gain an understanding of what is meant by responsibility. For example, focusing on the idea of justice may become the stem inquiry question – in this sense this is the big idea through which an understanding of responsibility is developed and understood. This is also not an argument about starting points and moving from over-view to depth or vice versa, it is an observation about the terminology of key concepts and related concepts.

The above point is illustrated further in the sections on supporting Conceptual Understanding which begin to explore what this might look like in individual subjects. Figure CO05 (PYP FPiP, p. 84) begins to suggest ways of thinking that are linked to central ideas and how this approach and ideas of key inquiry questions and promoting investigative learning might make access to the key and related concepts easier for both teachers and students. The key concepts/big ideas become tangible and there are approaches to investigating the questions that are posed.

The introduction section to MYP FPiP is crucial as it spells out the basis of conceptual understanding. But there are possible tensions here as to how concepts and conceptual understanding are perceived and developed within history curricula and teaching and learning within the subject. For example, in both the PYP and the MYP "students engage with a defined set of key and related concepts". These are defined in the prescribed syllabuses and clearly outlined on p.56 of the document with a helpful unpicking of these concepts, while related concepts for each subject are listed in Appendix 2 on pp.115-117. However, the relationship and mapping of all of these concepts remains problematic. In particular, there is some confusion about the differences between key and related concepts, especially as the document does state (p. 57) that "Teachers can develop additional related concepts to meet the needs of students and local or national curriculum requirements".

The MYP identifies 16 key concepts to be explored across the curriculum, namely:

Aesthetics	**Change**	Communication	Communities
Connections	Creativity	Culture	Development
Form	**Global interactions**	Identity	Logic
Perspective	Relationships	**Systems**	**Time, place and space**

(Those marked in bold are contributed by the study of individuals and societies, which includes History.)

The related concepts derived from History are:

Causality (cause and consequence)	Civilization	Conflict	Cooperation
Culture	Governance	Identity	Ideology
Innovation and revolution	Interdependence	Perspective	Significance

It is at least a little unclear why, for example, Change is a key concept but Causality only a related concept, Global interactions is key but Interdependence is related, and Culture, Perspective and Identity actually appear in both lists.

It may be that we have seriously misunderstood the distinction between key and related concepts, but, as we have pointed out earlier, we could find no research justification for it. There is surely a strong risk that teachers teaching the MYP may similarly be confused by the distinction.

In the case of History, it seems likely that any history curriculum would have to employ such terms as:

- Chronology
- Change and continuity
- Interpretation
- Significance

It is not clear whether these would become 'related concepts' in IB terminology or whether another set of terms needs to be employed.

At DP level (DP History Guide) there are still clear references to teaching and learning that is 'conceptually focused' but there would appear to be a great emphasis on a set of skills that enable students to be effective inquirers. What becomes apparent at this level is that we are presented with Key Concepts that overlap with, yet are not the same as, the related concepts for History from the MYP. These are explicitly set out as: (p.94-5)

- Change
- Continuity
- Causation
- Consequence
- Significance
- Perspective

Such clear articulation at this point does however, beg the question as to the basis that students at the start the DP programme are starting their studies with a different view of what key and related concepts are that have come from the MYP. Connections to prior learning in MYP make this very clear - references to key concepts (pp. 9-10), highlighting Systems, Change, Global interactions and Time, Place and Space, are not the same key concepts that have just been outlined. This 'chopping and changing' of the term key concepts seems potentially confusing and the need for standardisation in the use of terms seems evident. This is an issue we will discuss in more depth later in the report.

Approaches to CBTL

The distinction between fact-based learning and exploring concepts (PYP FPiP, p. 82) is a difficult area. Can concepts be explored without marshalling arguments, using evidence, thinking about perspectives and the significance of key information? – in other words information has to be handled and this invariably will involve facts. This is not purely a philosophical debate, but is about really thinking about what students need to do in order to grasp what concepts are and how these help them in learning and understanding. In relation to this point there is an obvious need to look at examples of curriculum planning and in particular pedagogical approaches.

The Introduction to the PYP Social Studies Scope and Sequence document clearly articulates the relationship of content and skills and concepts. There is an identification of 5 Strands and linked to this there is a clear emphasis on the inquiry approaches to be used.

- Human systems and economic activities
- Social organisation and culture
- Continuity and change through time
- Human and natural environments
- Resources and the environment

The document states that: 'The social studies component of the PYP should be characterized by concepts and skills rather than by content. However, schools should ensure that a breadth and balance of social studies content is covered through the units of inquiry.' (p.1) Thus the familiar PYP emphasis upon the linked ideas of concept-based and inquiry-led teaching is maintained.

The explicit emphasis upon conceptual understanding continues into the MYP. "The International Baccalaureate values education more as the transformation of personal understanding and the collaborative construction of meaning, less as the transmission of knowledge and rote memorization of facts" (MYP FPiP, p.14)

Approaches to assessment

The IB Learner Profile provides, in many respects, a very good starting point for thinking about the basis of a curriculum and developing pedagogical approaches that promote CBTL. The aim of all IB programmes to develop learners who 'strive to be' Inquirers, Thinkers, Communicators, Open-Minded, Balanced and Reflective. These are all hallmarks of good historians. These ways of thinking and dispositions enable students to develop through, what is often described as, a skills-based approach leading to a better understanding of substantive knowledge. There is one explicit reference to conceptual understanding under the heading Knowledgeable but this is not unpicked and this implies implicit understanding. It is recognised that these aspects of the profile are attributes valued by IB schools and in this sense they are 'headliners'. However, it would be helpful if there was more explicit engagement with what is meant by conceptual teaching and learning, particularly from the point of view of the history curriculum, given the points raised earlier about possible differences in how concepts are being referred to.

Outcome 3: Outcomes of the interviews

As described earlier, we conducted semi-structured interviews with ten senior IB curriculum leaders in the Learning & Teaching division. These interviews aimed to understand:

- The existing approaches and understanding of CBTL embedded in relevant curriculum documentation.
- How each IB programme develops conceptual understanding.
- Alignment and integration of concepts within and across the IB programmes.
- Aspects of curriculum particularly where CBTL is seen as successful in classes.
- Aspects of the planned curriculum presenting challenges to teachers and students.
- Identified discontinuities identified in curriculum documentation.

Interviews were transcribed and analysed using Nvivo 12 and in this section we will discuss the main issues arising.

Conceptual Understanding

All respondents recognised the importance of CBTL to ensure that IB programmes include content suitable to global and local contexts and to empower the learners of the future. They emphasised that:

> *"there has been a conscious decision to move away from a content-based curriculum, which can become out of date very quickly and also can be*

quite dry in terms of knowledge and understanding. I think what we are seeing is a shift away from seeing subjects as knowledge that you have to learn to be regurgitate in an exam to using the subjects as a lens which through to understand the world in which we live".

All identified conceptual understanding as the overwhelming goal of an IB education.

> *'the one thing that they (programmes and subjects) are all having in common is that approach to teaching which is teaching focused on conceptual understanding'.*

Respondents said that conceptual understandings were "deeper" understandings which allowed the application of facts in a range of contexts, learning in new content domains or transfer of knowledge across subjects, contexts or content. However, there was also a recognition that this is complicated by terminology.

> *"we do not have a clear idea of what we mean by conceptual understandings"*

Several interviewees were concerned that the lack of clarity about the nature of conceptual understanding could be confusing for teachers. The "conceptual approach" to the curriculum could mean a focus on developing conceptual understanding and/or a focus on planning the content of the programmes using specific concepts. In discussing CBTL these meanings were often used simultaneously.

There was a unanimous view that conceptual understanding was the goal of assessment in all the programmes but some ambivalence about the degree to which this involved assessment of particular key, related or disciplinary concepts. Interviewees were not sure whether conceptual understanding necessitated study of particular concepts planned into the programmes or whether conceptual understanding was the result of study of content though inquiry, in order to construct knowledge. Most emphasised that the assessment of conceptual understanding was demonstrated at DP level and in some MYP subjects through the assessment of understanding in a new context, rather than by assessment of identified concepts.

Concepts for organising the curriculum content

Colleagues discussing the role of concepts in the four programmes identified a confusion between concepts as "big ideas" which are "universal" and concepts as a form of learning beyond knowledge of facts.

> *"I think some of the tensions arise because we as an organisation have not been clear about what we mean by a conceptual approach and what we mean by conceptual understandings'*

They related this to the growing disciplinarity of the programmes as students progressed through their schooling. Both of these "types" of concepts were identified as important and were cited as ways of organising the curriculum content in programmes so that teachers could make the content (facts) contextually relevant to the students. However, there was an awareness that the term "concept" has been used very freely in documents.

… I did an audit recently of all the subjects in our group from PYP and through to DP in terms of the concepts in our subjects. And it is a mess! We talk about concepts differently and in the different programmes. We talk about concepts differently in the different subjects within the DP and we have different hierarchies of concepts and there is no consistency in the way in which we order them and there is no consistency in the way that we talk about them or we assess them.

IB colleagues recognised there were some issues with the language of CBTL, both across the programmes and within the programmes. Examples included what is, and is not, counted as a concept in different DP Programmes, or how a similar activity might be described in very different ways.

For example, in DP language and literature, seven concepts are identified for the whole group of subjects, but some of the assessment of language uses language specific to that subject (audience, context and purpose) and theatre uses a framework of TMAM (tension, motion, atmosphere and meaning) to guide reading in that area. This may be confusing for students and limit shared planning across staff groups.

The CP was interesting when considered against the questions underpinning a concept-based approach to teaching and learning. There were numerous examples of ways in which students could undertake authentic inquiry, select content and apply their developing understanding to new areas. It was noted that concepts were not simply a part of the design of the CP programme. This may be because the CP is heavily tailored to the needs of the specific students and it is, paradoxically, hardest to control from an IB perspective where elements of other programmes are included.

The origin of the conceptual approach in current IB documentation

Interviewees referred to concepts as derived from a philosophy of education unique to the IB, though the origins of the actual choices of key and related concepts had been lost.

"Concepts…are derived from or a function of, like, the IB philosophy of education."

Colleagues were aware of the impact of certain models of curriculum (Erickson) and planning (Wiggins and McTighe) and also recognised that the different histories of different programmes had meant the system of concepts had grown organically. This was identified as a major source of difference between the approaches to structuring content within programmes and assessing them.

Colleagues were uncomfortable with some of the approaches to curriculum development that had been relied upon, recognising that they were perspectives on planning rather than empirically based or demonstrated methods. They applauded approaches that emphasised the connection between learning outcomes and planning but were concerned about the dominance of unproven ideas.

"*there doesn't seem to be a lot out there in terms of what people are doing and I mean I have been reading some papers sort of that are coming out of New Zealand which are quite interesting*"

All the staff who spoke about the tension between "universal" concepts or "big ideas" and concepts within subjects related this tension to disciplinary or programme differences of outlook.

"the MYP approach to concepts is really at odds with how many DP curriculum managers see concepts. We don't see them as timeless and universal but something that should be contested and that students should be evaluating and assessing and looking at how they manifest themselves differently and in different contexts etc. So something that .. you know .. is not given but should be debated and I think that it is confusing that we talk about them differently and we do not have a clear idea of what we mean by conceptual understandings".

The opportunity to write a new course from scratch had offered staff the opportunity to balance the tension between content (facts) and concepts. The process of creating a concept-led programme was discussed by a number of interviewees, all of whom were very conscious of the need to be restrained in planning and not overload the programmes, to allow teachers to select appropriate contexts for the concepts and design inquiry-led, authentic learning experiences.

Concepts in the disciplines

Some colleagues explained the confusion about key, related and disciplinary concepts in terms of the evolution of IB programmes and gave a sense of direction of travel in the thinking about key, related and disciplinary concepts.

"*from 2014 the MYP took up the language of the PYP and to have key and related concepts but interpreted that differently. So in MYP related meant disciplinary. In PYP, their key and related meant really .. really big and then not as quite as big or important. In the MYP key means really big and interdisciplinary and related means important and more related to the subject matter because we do break the curriculum apart into subject groups because that is what you are able to more cope with that as you move into adolescence. In the DP there is a clear move to make the curriculum more explicitly conceptual but that is a very much on like a course by course basis by asking the curriculum developers and the processes that they follow that are there ways for you to be more explicit in identifying the big ideas that matter for this course*."

The successful use of concepts to organise subject groups, creating shared perspectives across a group of subjects, was identified to a greater or lesser degree by different strands. In social and cultural anthropology, history, global politics, the sharing of a perspective made creating conceptual structures challenging, especially where disciplines had a long- established history, but successful through identification of new, global perspectives. Here, concepts were clearly ways of thinking.

> *"so .. in 'global politics' they have got quite an explicit emphasis on things like 'power' and whereas the history had and was on things like 'change' and 'perspectives' but of course power is really important in history as well .. and 'change' and 'perspectives' are important in 'global politics' but .. it was really that to make it manageable for teachers it was looking at the courses that we were looking at and the examples that the students are going to be studying and the kinds of questions that we are likely to craft around them. What are the concepts that we think are most likely to be relevant to those experiences without excluding the other concepts as being useful?"*

However, in other areas, such as maths and sciences, colleagues noted that, at DP level, there was a more "knowledge based" structure to the experience necessary to undertake the subject successfully. Promoting ways of thinking across subjects remained important, but was not sufficient for students to be able to do the subject successfully and specific understanding had to be identified. Some colleagues discussed "threshold concepts" in this context. Colleagues felt this affected the planning of the subject because without having undertaken certain prerequisite courses, students did not have the knowledge to succeed in the subject.

Examples and disciplinary differences

When asked for good examples of "concept based teaching and learning", curriculum leads identified both teaching and curriculum planning from many disciplines. Examples of teaching typically explained that the problem was led by an inquiry question rather than by direct learning of content. The curriculum leads placed a strong emphasis on students understanding why they should learn a subject as well as stressing that a "concept based" approach was a way of building this into their curriculum strand.

When staff discussed concepts, some had preferred ways of naming them: threshold, abstract and concrete, key, transferable, etc. and struggled with using the terminology across programmes. This was particularly evident from different subject group perspectives.

Further examples were provided when asked about a synergy between facts and skills. This was something strongly identified across politics, business management, history, geography, anthropology where the triangle of concepts-content-contexts frames a shared approach. The transferability of ways of thinking between these subjects at DP was cited by a number of colleagues. In subject group four, examples of authentic, inquiry led teaching were also given as showing synergy between facts and skills and there was also emphasis on threshold concepts and the need for students to understand these before progress could be made. These represent fundamental disciplinary differences explored in TOK.

Interestingly, the tension between disciplinary and "universal" concepts was discussed by colleagues as a tension both between different programmes and perceptions of the pressures upon teachers at different programme levels. Colleagues identified an emphasis on pedagogy, most strongly in the PYP programmes, and an emphasis on content, particularly in DP programmes.

Several colleagues noted that, in PYP, the pedagogy of the programme was the focus of the guidance, whereas in DP, and to a lesser extent MYP, the teachers wanted much more specific guidance on content and took a much greater range of approaches to pedagogy. Although this is not evident in the documentation of the programmes, where both content, and assessment are specified at all programme levels (though less at CP), the pressure of examination accountability appeared to cause this to be strongly felt by curriculum organisers.

The architecture of change

All colleagues identified the seven-year curriculum review cycle as the key mechanism for change and some curriculum leaders recognised that this had to move at a pace appropriate to the teachers of these subjects. For many of the teachers, the IB approach is new and challenging and the goal of training all of them is one which constrains the change process. Curriculum leads aimed to undertake change informed by their contact with the teachers. The process of curriculum review is, of course, important to IB staff but also provides challenges in managing a coherent (though not identical) approach to CBTL.

> "*curriculum reviews - it is not that there is one curriculum manager who sits in the IB and makes its decision. It is done through an entire review process which includes researcher insights which are looking at the most relevant concepts in the research phase of the review plus IB practitioners and experts who are involved in the development stages of the review along with the internal IB staff. So there is that whole process of the outside in and so getting those insights from both our schools and external fields of knowledge if you like in that subject area that help craft and ultimately somebody has to make the decision when it comes down to it and there is obviously lots of discussion around that. But .. it is a case of there is never going to be a perfect answer but here is the best we can do in light of the understanding and the current research as it stands at the moment."*

Staff emphasised the importance of constant review, the stages of the review, and the need for a range of inputs, but also the difficulties inherent in those reviews, such as tracing past decisions and being able to build upon them. Some highlighted the way the review structure and shared use of concepts had enabled them to develop interdisciplinarity in the DP, particularly between Groups 3 and 4.

> *"we actually currently have two what I would call are interdisciplinary subjects and these are subjects that actually span .. you know .. two of our groups. So for example we have environmental systems and societies which actually have kind of group four which are the sciences and group three the individuals and societies as their kind of interdisciplinary frameworks. So students who take that subject actually get a group three and a group four kind of .. you know .. exposure and we have one other interdisciplinary subject particularly because we are moving towards a higher level interdisciplinary environmental systems and societies. We kind of want to make sure that whatever interdisciplinary framework that we have got is kind of robust enough and we know that there are many*

others .. there are many variants of interdisciplinary frameworks so .. so this is really very early in its kind of research and there will be input from the MYP and because they obviously have .. you know .. they already have some interdisciplinary kind of approaches in some of their subjects too and so it is still very early stages but it just an example of I think some of the thinking which as I say it is more that programme it is really kind of a cross programme initiative that we very much get involved in that".

This is an interesting idea and, given the lack of Key Concepts in the DP, interdisciplinarity was discussed in terms of considering topics from different perspectives, something which resonates strongly with the TOK work these students would already be doing.

Senior staff at IB recognised that using a conceptual approach to curriculum content and planning could be challenging for teachers. They identified this as particularly challenging for teachers at DP level, with their strong disciplinary backgrounds and experiences of other curricula. The Teacher Support Materials were seen as very important for teachers and guided them to plan in ways that included a statement of inquiry, key and related concepts. However, responsiveness to the needs of these teachers was thought very important in curriculum design and may have meant that review teams were constrained in the pace of change.

Promoting active, authentic learning pedagogies

The review of literature highlighted the close alignment between CBTL and active learning pedagogies and authentic activities. Curriculum leads were all strongly committed to this and to promoting it through their guides and teacher support materials. All the colleagues interviewed were able to offer examples of how this worked within their strands and the documents reviewed strongly endorsed such pedagogies and activities.

However, colleagues also recognised the tension between coverage of "content" and the ways this could be achieved using inquiry-led learning, dialogic discussion and authentic activities.

"*it is perfectly possible to teach a lot of our courses in quite a non-conceptual way and check the history course is an example and that is probably quite a good example. You have six sort of driving key concepts at the beginning and so things like causation and consequence and significance and perspectives. And they have informed of how the course was put together and how we selected what was going to go in it. But it is also still quite possible to take a more traditional, chronological kind of approach".*

The factors identified by respondents as important in determining how teachers approached the teaching of the subjects included the experience and support available for the teachers, the disciplinary background and training of teachers and feelings of time pressure for teachers, who may need to address non-IB assessments as well as the IB programme. Curriculum leaders gave examples of how a broad concept could be addressed in many different ways:

"So I think that is what I mean about a lot of it, is about how it is actually put into practice in the classroom is what makes the difference. Because these are a number of possibilities facing every teacher."

Colleagues noted that commitment to IB principles guided most teachers and that in-school training and teamwork was very supportive for teachers with limited experience.

"*it is very up front and even teachers for example on their unit plans … have to explicitly write a statement of enquiry that is meant to draw on one of the programme concepts and things and so I think that it is just so much more visible and explicit and up front probably in MYP."*

In terms of promoting active pedagogies, increasing teachers' experience of inquiry led planning and supporting the use of authentic activities, the support materials available through sample planning were seen as very important, alongside the discussion available to teachers.

"If you go back a few years our Teacher Support Material basically used to be the exam like the assessment samples .. in DP .. whereas now a lot of them have advice on teaching and learning .. or advice on formative assessment or .. they are kind of expanding beyond just .. here are examples of student work "

However, interviewees were confident that the IB support materials enabled teachers to offer a more conceptually led approach to the content of the programmes, often supported by the pedagogical guidance.

"the turning point was 2015 when we launched this approaches to teaching and learning in the DP project. We actually explicitly we put out this website and there was loads of like 30 little 5 minute videos of classroom practice and there is all sorts on there …that is probably the prime example of that shift I would say"

"*what I have seen in the approaches to teaching and learning is that one of the best ways is to .. to remain both disciplinary and interdisciplinary and in terms of the way that we are that we would like students to be able to operate .. that concept based approach are a good framing mechanism for that .. for that interdisciplinary .. the benefit of interdisciplinary understandings and to take place*."

The Teacher Support Materials have clearly been seen as a vital part of teacher training, development of teacher philosophies and implementation of CBTL pedagogies.

"*it is not just about if only you just need to design this beautiful programme and of course everyone would just then be able to get on with it .. but they wouldn't and there would be big gaps. But we have to put in as much time in to the Teacher Support Materials as we do with the guide itself. So if we want active learning and we want teachers to be using discourse and peer assessment and all the peer learning and all this other* *stuff. We have to support the teachers and with the TSM and .. and the curriculum and the videos and say look .. here is .. is some great curriculum and there are some really good ideas on how this will look in the class room otherwise you are just getting .. you know .. rote learning culture and .. you know .. can't compute."*

In terms of curriculum planning, interviewees felt that the most helpful way of supporting teachers to pursue inquiry lead teaching and authentic activities was to reduce the specified content of the programmes. This was felt to give teachers space to develop authentic materials relevant to their context and enable students to study them in depth.

"if you are going to say that then you need to give space in the curriculum for teachers to be able to do that inquiry. Because that enquiry takes time .. and also not just space .. but provide them with the support to access the kinds of materials that they are going to need to use for students to do the kind of do the kind of enquiry that you want. And .. you know .. we make assumptions that schools have read .. and have the access to the kind of resources that they are going to need and very many of them don't or they don't have the tools to know as teachers .. how to navigate through the amount of information that is available."

Assessment of programmes and CBTL

Colleagues spoke positively about assessment as part of all the programmes. The principles of assessment set out in documents at PYP and MYP level were particularly applauded because they allowed teachers to identify conceptual learning outcomes and assess them flexibly. For example:

"The MYP in a subject like language acquisition or arts .. where the formal assessment of the course happens in a .. what we call an e-portfolio .. where teachers are collecting evidence of students learning from a variety of tasks. All of the tasks in that unit will have been built with a particular set of key and related concepts in mind and so all the learning in that .. in that unit that we would start for teachers and then they finish themselves is geared up around some combination of them. So we are using in that instance the students ability to .. you know .. successfully engage with one set of concepts as a proxy for all of the other work that they have done that year"

This statement suggests a focus on conceptual understanding and the willingness to sample understanding rather than assess whether certain concepts were understood. Colleagues recognised the assessment of conceptual understanding and found the PYP continua particularly useful in this respect. However, it is notable that these continua do not address the key concepts but rather the strands in the PYP Scope and Sequence documents. Likewise, the related concepts are addressed at different points in MYP, rather than developed through the MYP.

An example of how colleagues saw assessment as related to CBTL is:

"I would like to see that there is a strong relationship either between the debatable questions and the statement of inquiry to see if students are

taking these specific facts and examples and connections that they draw between them and making a leap from that to a slightly different situation and summative tasks and so that there is a measure of the students being able to use the concepts as the bridge from the specific example that they have developed in class into a novel or slightly different situation in a summative task."

This quotation highlights the importance of assessment and of conceptual understanding, but not of the key or related concepts at PYP or MYP. Both formative and summative assessment were discussed by staff and making these "conceptual" was seen to involve knowledge transfer, or conceptual understanding, rather than the assessment of the particular concepts planned into the curriculum.

This may be something to do with the development of the programmes. One colleague noted, in relation to assessment, that:

> *"because the ATL and the Learner Profile you know .. they are relatively new .. in terms of an IB .. and as I said before they just became a layer that we sort of just put on top of everything else and it is only now that we are starting to think about designing the curriculum with those things in mind .. and they are at the forefront of our minds and .. you know .. whereas before it was a little bit of tweaking but not really a restructuring .. and now that we are starting to restructure and rethink this is where the challenge is coming actually."*

Conclusions and recommendations

A summary of the outcomes

a) The literature review

- A detailed review of research material was carried out, during the course of which 158 papers were read and their insights used to arrive at a set of principles against which IB programmes and subjects could subsequently be audited. This literature review was organised around four main headings (see page 23).

- Concept based teaching and learning (CBTL), according to the literature review, aims to promote the learning of concepts which facilitate the generation and understanding of ideas, the transfer of knowledge and skills, and a critical or reflective perspective towards knowledge itself.

- A further literature, based in research into professional areas outside of schools, sites CBTL firmly within disciplines and professional communities of learning such as HE level engineering and nursing, each of which has its own disciplinary conventions.

- Particular features of pedagogy are associated with CBTL in the literature, including inquiry-led learning, authentic learning activities, dialogic discussion and flexible integrated assessment.

- A number of key principles were derived from the literature and these principles were organized into 5 themes: The nature of concepts, Concept development, Concept-based teaching – key features, Classroom interaction in concept-based teaching, and Assessing conceptual understanding. The full list principles and thematic grouping are given on page 68 of the report.

b) The audit of IB programme and subject documentation

- A limited number of identified concepts are used to structure the content of the IB programmes. In PYP, MYP, DP and CP, these include both concepts identified as "big ideas", which are seen as trans- or interdisciplinary and also disciplinary concepts which set out the learning content of the programmes.

- The terminology distinguishing "big idea" concepts which are "universal" and not confined to a subject is confusing. In PYP, Key Concepts are treated as both transdisciplinary and disciplinary. In MYP, Related Concepts are disciplinary and Key Concepts are interdisciplinary. Concepts at DP and CP are largely disciplinary, although they are also used to make links across subject areas.

- The distinction made between Key Concepts and Related Concepts is not, as far as we could tell, derived from the literature, which instead claims that concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts.

- The term 'concept' is used differently in Mathematics than elsewhere. In most of the Mathematics documentation, the term 'concept' is usually linked with the word 'mathematical'. This generally refers to knowledge in this subject and is often partnered with the term 'skills'. There is not the sense of concepts as overarching, categorising ideas that is found in other subjects.

- The origins of CBTL in the IB programmes is unclear and the 'organic" development of ideas is one reason for the discontinuities in terminology, if not in principles.

- PYP scope and sequence documents contain a number of structures to guide planning of a syllabus and inquiry lead units. In the example of Arts, for instance, these include subject (for example in the arts - dance, drama, music, visual arts); strands (responding, creating), related concepts (interpretation, performance, imagination and techniques); key concepts (form, function, causation, change, perspective, connection, responsibility). The learning continua set out phases of achievement for each strand, which are described in terms of conceptual understanding. The Approaches to Learning (ATL) document for PYP also sets out thinking skills which may be considered as a description of conceptual understanding and which detail the development of conceptual understanding.

- MYP Subject Guides set out a number of structures to support the development of a syllabus. The example of the Arts underlines the differences in structure from the PYP. This MYP Arts Guide includes: Key Concepts (aesthetics, change, communication and identity), related concepts (24 related concepts divided among visual and performing arts); global contexts to be explored (identities and relationships, orientation in space and time, personal and cultural expression, scientific and technical innovation, globalization and sustainability, fairness and development); statements of inquiry (related to key, related and global concepts); inquiry questions (including conceptual questions); Approaches To Learning (including indicators of conceptual understanding such as thinking skills, social skills, self-management skills, communication skills, research skills). In addition, there is subject specific guidance for dance, drama, music, media and visual arts.

- At DP level, the Arts break down into a range of subjects. Theatre, for example, includes core areas (presenting theatre, theatre in context and theatre processes) each of which is mapped to four core activities: creating theatre based on theatre theory (HL only); working with play texts; examining world theatre traditions and performance practices; collaboratively creating original theatre. These are linked to a range of assessment tasks (both internal and external) and command terms (imperative verbs).

- There are significantly different structures both within subjects and across programmes and the conceptual nature of the curriculum is included in many of the structures - including ATL, key and related concepts, learning outcomes, phases and continua, assessment tasks and assessment criteria.

- All the IB programmes showed a clear commitment to the development of conceptual understanding by students, in all subject areas.

- The expression of conceptual understanding becomes progressively more discipline-focussed as the student proceeds through the programmes.

- Much of the teacher support for CBTL is included in the ATL and TSMs. At the same time, curriculum leaders aim to balance the amount of specified content to promote CBTL pedagogies.

- Curriculum leaders within IB see a concept-based approach to teaching and learning as a longer-term goal of the review process for programmes and subjects within the programmes.

- One limitation of the project is that it has not been able to establish how teachers use the specifications for conceptual understanding (ATL, skills etc.) or key and related concepts - only their role in the written curriculum.

- There are also some gaps in the documentation we were able to access where it was difficult to find evidence that the principles derived from the literature did actually inform the IB approach. Looking at the nature of these gaps, it is clear that they mostly involve principles which focus upon actual classroom action (rather than underpinning curriculum structures). This might suggest a gap in terms of the documentation, rather than recommended pedagogic practices. Perhaps there is a need for further documentation, and maybe CPD, to focus on pedagogy in order to help ensure that the sound theoretical underpinnings given in the programme guides might best be translated into effective classroom action.

- The learning outcomes of the DP and MYP programmes are clearly aligned with the disciplinary concepts within each strand.

- The model of assessment presented in IB documentation at programme level offers numerous opportunities for concept-based assessment through both internal and external means. However, there are differences between programmes in how this is interpreted. Most assessments are geared towards assessment of conceptual understandings and assessment of disciplinary concepts (DP) and related concepts (MYP). The assessment of key concepts themselves is not a focus of assessment.

- In the MYP the assessment criteria are described using a familiar statement-based structure. In the MYP Arts Guide, the end of year 5 level descriptors for Knowledge and Understanding, for example, centre around three statements with progression indicated by the use of either of the adjectives *limited*, *adequate*, *substantial* or *excellent*. Such an approach is only useful if the teachers using the descriptors all share an understanding of the precise meanings of these adjectives.

- Most IB programmes, even at MYP and DP levels, do include some element of more student-centred assessment, from the mathematical exploration required for Mathematics DP to the assessment of practical work in Science. Such inclusions clearly support the inquiry-based philosophy which is so central to all IB programmes.

How does each IB programme develop conceptual understanding?

The IB programmes (PYP, MYP, DP and CP) are based on an approach to students' learning that values the construction of student understanding through individual and social inquiry. This is evident in curriculum guidance that frames knowledge not simply as the acquisition of facts and skills but as the construction of cognitive structures to permit generalisation, transfer and originality in knowledge. The curriculum guidance contains not only guidance about the content and nature of the programmes but also pedagogical advice, supported by the Teacher Support Materials. The approaches to pedagogy advocated within curriculum documents are broadly consistent with the approach to learning in the documents. All documents take an inquiry-led approach, although disciplinary differences mean that this appears somewhat differently in different subjects, as might be expected. A contrast can be made between recommended pedagogy in Science, where inquiry is embedded to the extent of almost being taken for granted, to that in Languages, where an inquiry approach is recommended but not really exemplified.

All documents present the goal of an IB education as “conceptual understanding” and curriculum planning, teaching and assessment advice is strongly geared towards this shared objective. It is included explicitly as a goal in programme documents and is also evident in the ATL, TSM and subject guides at all levels. The approaches to learning (ATL) documents specifically promote the skills to acquire, transform, link and transfer knowledge and so may be seen as a key vector of conceptual understanding.

To what extent does the role and integration of concepts align within and across the IB programmes?

Concepts are used to structure curriculum content within the programmes. Concepts are presented as: “powerful, broad and abstract organizing ideas that may be interdisciplinary, transdisciplinary or subject-based”. Concepts both as “big ideas” and as elements of disciplinary or transdisciplinary content within a subject are included in the MYP and PYP programme documents. The PYP FPiP contains a chart differentiating facts from concepts, which aggregates concepts with their possible functions.

The IB approach to transdisciplinarity at PYP level, and interdisciplinarity at MYP, DP and CP level aims to promote deep understanding, facilitate transfer of knowledge and ensure student understanding is not limited by artificial “subject boundaries”. This is included in the different programmes in different ways which reflect the growth of disciplinary approaches to knowledge, understanding and learning as students proceed through their educational lives.

Concepts as “big ideas” (trans-or interdisciplinary concepts) are presented as “Key Concepts” in PYP and MYP, whereas other concepts are presented as “Related Concepts” in PYP and MYP or as disciplinary concepts in the DP and CP documents, Scope and Sequence documents and Subject Guides. Guidance in curriculum documents says that there may be an unlimited number of related concepts, particularly where other curricula are in place in a school. In addition, at PYP level, the scope and sequence documents identify ways in which the Key Concepts can be approached from either a generalised level or a disciplinary level.

The role of the Key Concepts is somewhat confusing. The role best exemplified in the chart mentioned above is one of guiding the creation of context-spanning questions which promote transfer of knowledge. At PYP level the specific role of the Key Concepts is given as one of shaping questions about the content of an inquiry and helping students to “think critically about big ideas”. However, the questions related to each concept in PYP FPiP and the Scope and Sequence documents suggests a role for key concepts in defining teaching content as well as linking knowledge with other content. The way this is presented varies by subject. For example, PYP Arts illustrates key concepts with questions to shape the content of the inquiry where Science illustrates the same concepts with statements about the particular concept from both a disciplinary and generic perspective.

In MYP the same subjects treat the increased number of key concepts differently, although they have a role in promoting the planning of links between curriculum areas. In MYP different key concepts are specified for each subject strand to promote interdisciplinarity. Subject guides at MYP relate key concepts to the statements of inquiry (rather than the other way around, as in PYP) and some subjects, such as science, show a different approach to generating questions, which may be factual, conceptual or debatable. It is impossible not to conclude that Key Concepts are less universally useful in the planning of MYP questions and have a role in structuring interdisciplinarity in some subjects (science) but not in others (arts).

The role of related concepts is to guide choices of content which may be studied without specifying the facts to be learnt, so that teachers may choose content relevant to global and local contexts.

In DP, the inclusion of TOK and the Extended Essay has an important role for CBTL. The study of the nature of disciplines- the ways knowledge is valued, created and discussed has a strong interdisciplinary effect and may be seen as a key route to the creation of concepts for knowledge transfer and reflection. This is an important part of the approach to CBTL.

The IB commitment to this approach to learning stems from its earliest guiding principles but has been shaped in different ways across each programme, based on the spread of particular perspectives and curriculum development innovations during the review cycles for subjects.

How do IB approaches to CBTL compare with best practices and contemporary developments in the field of CBTL?

The developments in teaching and learning related to CBTL are broadly reflected in the IB programmes.

The recent emphasis on a knowledge-based curriculum is a particular challenge for IB, providing as it does a global curriculum in which different elements of knowledge will be deemed essential/desirable in different contexts. Specification of content, therefore, must be through ideas such as "transdisciplinary themes", concepts, skills etc., which need to relate to locally specified knowledge content.

The programmes in the IB strongly espouse a synergy between facts and concepts by structuring the content using concepts and skills but asking teachers to identify the appropriate facts within the programme. The synergy between facts and concepts is emphasised by the way the programmes are specified, which demands that teachers make choices in content.

The IB programmes strongly prioritise inquiry learning, although documentation does mention the use of direct teaching, particularly for whole class issues at PYP level. The documents emphasise direct teaching as a basis for developing procedural knowledge rather than complex learning experiences. Interviews with IB colleagues suggest that many teachers, particularly those new to IB, find inquiry-led teaching to be challenging, and often new to them, and, therefore, this may be why the examples given for teachers are all inquiry-led. However, recent debates about instruction, including concept-based teaching, suggest that students' learning in some curriculum areas is enhanced when the information presented is explicit, logically organized, and clearly sequenced. It is fair to say that the balance between inquiry-led approaches to teaching and direct instruction focused on knowledge is an on-going tension for the IB, as it is for most other school systems.

Planning, teaching and assessing a concept-based curriculum places demands on teachers in terms of their subject knowledge, their teaching skills and their understanding of the IB curriculum and the values it promotes. The IB curriculum documents contain expectations about the understanding and familiarity of teachers with the documents and structures they are teaching and those of the programmes into which their students will be progressing. The documents require considerable focus on the part of teachers to distinguish the many structures, terms and activities. Although a glossary and teacher support materials are provided, all teachers using this material would require significant preparation in terms of induction and training. The TSM and examples available to schools make this training possible within schools but the plethora of terminology and structures means that this remains demanding.

Curriculum managers recognise that inquiry-led approaches to learning demand in depth examination of topics and this involves a good deal of student time. In some DP subjects, this has led to concerns about curriculum overload. Curriculum managers have taken steps to address this through careful selection of essential items of the curriculum to allow teachers the space to plan and teach activities likely to encourage in depth research and links between aspects of conceptual understanding.

The PYP, MYP, DP and CP all build on the basic assumptions about accommodation and assimilation of new learning set out in the review of literature, taking a social constructivist approach. This is evident in documents through the emphasis given to discussion, paired and group work, dialogic talk and reflection. Although reflection is no longer a PYP key concept it remains an important part of the inquiry and learning process. This emphasis on reflection and metacognitive skills is an important indication of the social-cognitive stance taken in PYP documents. DP, CP and MYP documents also take a social constructivist approach to learning and teaching, including the strategies discussed above, among others. The increased role of student self-awareness and, particularly, agency is evident through all the programmes, not only through CAS but as an integral part of PYP and other programmes.

The use of concepts in planning for depth, breadth and complexity is best evidenced in the FPiP documents for each programme. Whilst key concepts in PYP are said to guide transdisciplinary units and the Exhibition, they are not directly assessed. Assessment focusses on conceptual understanding, in particular of the strands in the PYP scope and sequence documents through the learning continua. Much of the content of the phase descriptors in these continua is conceptual understanding, but it is based in the disciplinary concepts described as strand content (for instance, in maths: data handling, measurement, shape and space etc.). It is, therefore, these concepts which are revisited repeatedly as students progress through the PYP. In MYP there is not a hierarchy of revising key or related concepts, as teachers may choose which to engage in which units. Moreover, assessment is of strands within subjects and the assessment criteria include conceptual understanding of specified areas as well as skills, but do not directly assess concepts. The MYP Personal Project has a particular place in the MYP, which may well engage the interdisciplinary approach aimed at by key concepts, but does not set out to do so specifically. In DP/CP the assessment of concepts is built into the subject assessment, but these are the disciplinary concepts of the subject. There are shared themes in some subject groups but systematic revisiting of concepts is based on disciplinary hierarchies, not key or related concepts.

The goal of IB programmes is to ensure that learning is authentic by making the selection of curriculum content based in both global and local contexts. This is why concepts have been specified as curriculum structures and why they are used to guide the selection of content and questions both relevant to the student and also globally relevant. Taken with the IB commitment to action and agency, this is a carefully structured curriculum to promote authentic activities. Such activities are promoted in the Principle into Practice guidance for all programmes and the Subject Guides. CP is particularly well placed to ensure that students undertake authentic activity. The Exhibition and MYP Personal Project are further examples of this. It is, however, the case that the emphasis upon 'authenticity' in curriculum content does significantly lessen as one moves through the programmes. This may be a simple corollary of the move towards disciplinarity from PYP to DP. This move towards disciplinarity within subject programmes at DP/CP level is clearly, from their interviews, a matter of concern for IB Curriculum leaders. However, this must be considered in the context of the broad and balanced content of the IB curriculum as a whole. The TOK course, in particular, has an important role in ensuring DP students are aware of the paradigmatic constraints of disciplines and are able to recognise paradigmatic assumptions and practices. This places those students in a virtually unique position in entering higher education.

Recommendations

a) Definitions

- The term "concept", and its subdivision into 'key concepts' and 'related concepts' is used freely in the documentation. The impact of this on teachers is unknown, but we did pick out some potential confusions. These, interestingly, were also recognised by curriculum leaders. We recommend that the use of these terms be reviewed within the programmes. Our suggestion would be to reserve the term 'key' for concepts which are truly of central importance to an area, and use the term 'related' for concepts which may be seen as of lesser importance. We recognise that this would make it harder to signal interdisciplinary links, as concepts, key or related, may have different meanings in different disciplines. But this problem already exists and we are not convinced that the present key/related distinction gets round it.

b) Teacher development

- Teachers are currently required, at PYP, to engage with transdisciplinary questions, key and related concepts, strands and phases. It would be worthwhile making more of the work carried out in a range of settings to establish whether further work to guide the asking of questions for inquiry, currently required through key concepts, could be presented for teacher use.

- It may be that IB teachers could be given more guidance in the use of direct instruction that meets these criteria, in the context of inquiry, so that they can achieve a flexible balance of direct and inquiry-led teaching which best meets the needs of learners.

c) *Transferability and authenticity*

- Some consideration needs to be given to the idea of transferability, of both factual knowledge and conceptual understanding (generalisability), within the IB programmes. We have raised some doubts about this, stemming from our analysis of extant research literature, and suggested the need for a closer look at concepts such as situated cognition and embodied cognition. This should not be interpreted as a negative comment, however. The field of situated cognition has given rise, through the work of Lave and Wenger (1991), to a very powerful model of social learning which has, in our view, a great deal possibly to contribute to IB education. Learning seen as a *situated* activity has as its central defining characteristic a process Lave and Wenger call legitimate peripheral participation, referring to the idea that learners inevitably participate in communities of practitioners and that the mastery of knowledge requires newcomers to move toward full participation in the sociocultural practices of a community. 'Legitimate peripheral participation' provides a way to speak about the relations between newcomers and more experienced members of the community, and about activities, identities and communities of knowledge and practice. It concerns the process by which learners become part of a community of practice. The social process of engaging in the community includes the learning of the knowledge and skills needed in that community. Such a community of practice view of learning is already embedded, if not named, in the PYP model of teaching and learning and we suggest there is a lot of scope for integrating it into the MYP and DP/CP.

- Considering a community of practice viewpoint as the basis for pedagogical organisation would also, we think, help clarify the issues surrounding the concept of authenticity. This is relatively easy to implement at PYP level, where curriculum content is much less tightly circumscribed. At MYP and DP/CP levels, because of more tightly defined curriculum content, it gets harder to ensure that students perceive their curricula as authentic and see the enterprise as a community of practice, with the attendant social and collaborative aspect, may help these students make links between subject material and their lives outside school.

d) *Future developments*

- Some further thought could be given to the nature of the learning process, taking into account the implications of schema theory. It will, we feel, be helpful in many ways for teachers to be explicit with their students about the ways in which learning works.

- As we were unable to match several key principles arising from the literature review to programme documentation, we recommend that special attention may need to be given in future documentation and CPD to practical teaching strategies for teachers at all levels. Concepts such as dialogic teaching, and active learning need to be actively considered by teachers of IB programmes. There are also a number of current "pedagogical debates", that is, fairly recent developments which are as yet unreflected in IB programmes, such as knowledge-focused curricula, and cognitive load theory. IB teachers probably need to be brought up to speed about these.

e) Some limitations

- This project was not able to establish how teachers use the specifications for conceptual understanding only their role in the written curriculum. It would be interesting to know which structures and terminology teachers actually use in their planning, teaching and assessment of students at each programme level and we recommend that a future project might explore practices in this and perhaps produce some case studies in this area.

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Appendix 1: Audit Report Cross-programme

Principle	**Material audited** (1) PYP FPiP 2018 (2) MYP FPiP 2017 update (3) DP FPiP 2015	
	References in documents	**Comments**
Concepts are mental representations of categories of objects, events, or other entities.	Related concepts explore key concepts in greater detail and also add depth to the programme. In contrast to the broad key concepts, related concepts are more narrowly focused (1) The key concepts contributed by the study of arts are aesthetics, change, communication and identity. Related concepts promote deep learning. They are grounded in specific disciplines and are useful for exploring key concepts in greater detail. (2) Conceptual learning focuses on powerful organizing ideas that have relevance within and across subject areas (3)	*The distinction between key and related concepts does not come from the research literature* *The key/related concept distinction here is not, as far as we can tell, derived from the literature. But it may here be a useful way of bringing together a focus on disciplines and an interdisciplinary approach.*
Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings", "essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.	Concepts are powerful, broad and abstract organizing ideas that may be transdisciplinary or subject-based (1) A concept is a "big idea"—a principle or notion that is enduring, the significance of which goes beyond particular origins, subject matter, or place in time (2) A concept is a big idea—a principle or conception that is enduring, the significance of which goes beyond aspects such as particular origins, subject matter or place in time (3)	*Adds the transdisciplinary angle* *It is not clear that a concept has to be an 'enduring' principle. The literature refers to 'enduring understandings'* *Consistent with the definition in MYP.*
Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts.	Key concepts provide a lens for conceptual understandings within a transdisciplinary unit of inquiry; related concepts provide a lens for conceptual understandings within a specific subject Concepts represent ideas that are broad, abstract, timeless and universal. Key concepts drive learning experiences and help to frame a unit of inquiry. By identifying and investigating key concepts, students learn to think critically about big ideas.	*Distinction between key and related concepts is unusual* *Literature tells us that concepts vary in terms of universality and hence timelessness* *Literature suggests giving some emphasis to teaching of higher level concepts.*

Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts.	Young students come to school with their own experiences, theories and capabilities. While a student's prior knowledge may align with the subjects identified by the PYP, young students do not experience the world through these lenses. Instead, they learn from their environments, people around them, seeing experts at work, questioning and reflection, with little need for specific knowledge instruction (1)	*Teachers build upon this previous experience*
Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.	A concept-driven curriculum, another cornerstone of an IB education, helps the learner to construct meaning through improved critical-thinking and the transfer of knowledge and understanding. In transdisciplinary learning, concepts play a particularly important role in "linking operators" of knowledge (Klein 2004). Whereas knowledge and boundaries between disciplines can change over time (Nicolescu 2014), concepts are organizing ideas that have relevance within and across subjects (Erickson 1998; Fogarty and Stoehr 2008) as well as across national and cultural boundaries. In effect, concepts are transdisciplinary. (1) (p. 50) Transfer skills is listed as one of the sub-skills (under Thinking Skills) in the Approaches to Learning skills map on p.61 "Reflecting on students' existing competencies, and through ongoing documenting and monitoring of students' emergent skills, teachers provide opportunities for students to be exposed to new skills, to further develop existing skills and to apply and transfer skills in various contexts (Berliner 2004)."(p.62) Student activities to develop what is then referred to as "Information Transfer" are listed on p.66: • Use memory techniques to develop long-term memory. • Inquire in different contexts to gain different perspectives. • Make connections between units of inquiry and between subjects. • Transfer conceptual understandings across transdisciplinary themes and subjects.	*This may happen but it seems not to be universal* *Concepts may not actually generalize unless deliberate prompted* *Transference may not be as simple as this.* Erickson (2007) refers to this as 'intellectual synergy'.

	- Combine knowledge, conceptual understandings and skills to create products or solutions. - Apply skills and knowledge in unfamiliar situations or outside of school. - Help others develop conceptual understandings and skills. (p.66) Concepts help to: - build understandings across, between and beyond subjects - integrate and transfer learning to new contexts.(1) (p.79) Concepts place no limits on breadth of knowledge or on depth of understanding, and therefore are accessible to every student (1) (p.79) Key concepts are broad, organizing, powerful ideas that have relevance within and across subjects and disciplines, providing connections that can transfer across time and culture. (2) (p.15) Effective teaching and learning in context helps students and teachers to … build up the skills and experience necessary to transfer learning from one context to another (2) (p.17-18) The transfer of skills is one of the key Approaches to Learning (ATL) skills, elaborated in detail in Appendix 1 of the MYP From Principles to Practice guide. It is summarized by the question: "How can students transfer skills and knowledge across disciplines and subject groups?" and a number of strategies are suggested, under the heading of "Using skills and knowledge in multiple contexts. - Use effective learning strategies in subject groups and disciplines - Apply skills and knowledge in unfamiliar situations - Inquire in different contexts to gain a different perspective - Compare conceptual understanding across multiple subject groups and disciplines - Make connections between subject groups and disciplines - Combine knowledge, understanding and skills to create products or solutions - Transfer current knowledge to learning of new technologies	

	• Change the context of an inquiry to gain different perspectives" (p.114 This is a similar but not exactly matching list to that given in the PYP Guide. Curriculum … promotes conceptual understanding and knowledge transferable to new contexts (3)	
Crucial to the development of scientific/academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.	(Also in MYP guide, (p.13)) The exploration and re-exploration of concepts lead students towards engagement with complex ideas, including the ability to transfer and apply ideas and skills to new situations (3) Concepts reach beyond national and cultural boundaries. They help to integrate learning, add coherence to the curriculum, deepen disciplinary understanding, build the capacity to engage with complex ideas and allow transfer of learning to new contexts.(3) CP students engage with a challenging programme of study that genuinely interests them while gaining transferable and lifelong skills in applied knowledge, critical thinking, communication, and cross-cultural engagement.(3) (p.16) DP courses help learners to construct meaning as they become increasingly competent critical and creative thinkers, able to transfer knowledge and take responsibility for their own learning. (3) (p.70)	*Needs more deliberate focus on transfer, including raising students' conscious awareness*
Students learn best when: 4. concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general; 5. concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as	As PYP teachers become familiar with concepts and conceptual understandings, they identify authentic links between subjects and within the programme of inquiry. Single-subject teachers and support teachers connect learning through the programme of inquiry's central ideas wherever the learning is authentic (1) When teachers support student agency, they … foster authenticity for students to explore their interests by giving them open-ended tasks (p.5) (1) Action (p.24) and Agency The purpose of the PYP Exhibition is given as: "to provide students with an opportunity to demonstrate the attributes of the learner profile in authentic contexts" (p.34) Authentic learning experiences – closely connected with	*Authenticity is a key feature of effective concept learning*

isolated facts to be learned; 6. the difficulty of a task meets student capabilities.	transdisciplinarity. Themes are said to "allow for authentic embeddedness of subject areas" (p.48) Inquiry is purposeful and authentic (p.72) One of teacher's roles is "identifying authentic opportunities for thinking and responding like historians, athletes, artists, scientists, and so on, within a unit of inquiry" (p.93) Effective assessment is described as "Authentic: It supports making connections to the real world to promote student engagement" (p.97) "Authentic" appears 58 times in the document. MYP the word "authentic" appears 26 times, with at least 10 of those being in reference to student honesty in assessment DP only 12 uses of the word "authentic", with most being concerned with student honesty in assessment.	
The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects. Such categorisations function as "hooks" on which learners can "hang" new information.	Students co-construct beliefs and mental models about how the world works based on their experiences and prior learning. They integrate new knowledge with their existing knowledge and apply these understandings in a variety of new contexts They learn to recognize patterns and see the connections between discrete examples to strengthen conceptual understandings (p.79) Concepts represent the vehicle for students' inquiry into issues and ideas of personal, local and global significance, providing the means by which the essence of a subject can be explored.(3) Students understand when they build connections between the 'new' knowledge to be gained and their prior knowledge. More specifically, the incoming knowledge is integrated with existing schemas and cognitive frameworks. Since concepts are the building blocks for these schemas and frameworks, conceptual knowledge provides a basis for understanding (3)	*Using concepts to organize new information*
Key features of effective concept-based teaching models include recognising that	Students co-construct beliefs and mental models about how the world works based on their experiences and prior learning	*Learning seen as collaborative activity*

both facts and concepts are essential elements of curriculum, and that learning is at its most effective when organised as a collaborative activity.	DP courses are based on an interrelationship of concepts, content and skills all viewed as equally critical to student learning. Content is critical to building conceptual understanding. Concepts are made concrete through content. Skills give access to conceptual understanding and allow students to actively engage with content.(3).	*This a reference to the influence of Erickson's synergy*
Teachers ask a great many questions in lessons but need to consider varying the types of questions, to include not just factual questions, which focus on content that students need to know, but also conceptual questions, which connect this factual content with the concepts which underpin it, and open questions, designed to provoke thought and discussion.	Carefully crafted questions, wonderings and provocations stimulate critical-thinking skills (1)	*Key importance of teacher questioning*
Active learning pedagogies have been shown to improve student conceptual understanding and involve students actively reflecting upon what they are learning.	Teachers and students use statements of inquiry to help them identify factual, conceptual and debatable inquiry questions. Inquiry questions give direction to teaching and learning, and they help to organize and sequence learning experiences.(2)	
Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.	The structure of observed learning outcomes (SOLO) taxonomy (Biggs and Collis 1982) outlines five levels of thinking: one level where students have no prior knowledge or understanding, two surface levels of knowledge and two deeper levels of thinking (conceptual understandings) (1)	*Use taxonomies to develop rubrics and assessment tasks to move beyond traditional examination tests*

A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.	Highly effective assessment is authentic: It supports making connections to the real world to promote student engagement. And varied: It uses a wider range of tools and strategies that are fit for purpose in order to build a well-rounded picture of student learning (1)	*A single testing instrument is clearly unable to achieve all these things.*
Teachers can detect changes in learners' conceptual understandings by looking for key indicators.	Progress in conceptual understandings is evident when the use of abstract concepts increases, connections are made between multiple concepts to explore the central idea, understandings are transferred to more complex contexts, actions are informed and taken based on existing and new understandings of the central idea (1) The assessment criteria for Knowledge and Understanding centre around three statements: The student: i. demonstrates awareness of the art form studied, including use of appropriate language ii. demonstrates awareness of the relationship between the art form and its context iii. demonstrates awareness of the links between the knowledge acquired and artwork created. Progression is indicated by the use of either of the adjectives *limited*, *adequate*, *substantial* or *excellent* being attached to the word *awareness* in each of these statements (2).	*Useful model of the purposes of assessment – implications for the form* *There is no attempt to define what is meant exactly by these adjectives nor, as far as we can tell, any exemplification.*
One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.	Feedback has been identified as one of the most effective teaching practices (Hattie, Timperley 2007) and should, therefore, form the core of assessment. Effective teacher feedback offers opportunities for reflection and action. It encourages learning adjustment, promotes continuous improvement and celebrates success (1)	*The role of feedback correctly identified*

Appendix 2: Audit Report for Theatre Studies

Principle referred to	**Material audited** (4) PYP FPiP 2018 (5) PYP Arts scope and sequence 2009 (6) MYP Arts guide 2017 update (7) Middle Years Programme Subject Brief 2014 (8) Diploma Programme FPiP 2015 (9) Diploma Programme Theatre Guide 2017 update	
	References in documents	**Comments**
1 Concepts are mental representations of categories of objects, events, or other entities.	Related concepts explore key concepts in greater detail and also add depth to the programme. In contrast to the broad key concepts, related concepts are more narrowly focused (1) The key concepts contributed by the study of arts are aesthetics, change, communication and identity. Related concepts promote deep learning. They are grounded in specific disciplines and are useful for exploring key concepts in greater detail. (3) There is no reference to concepts or concept-based teaching in this document. (4) Conceptual learning focuses on powerful organizing ideas that have relevance within and across subject areas (5)	*The distinction between key and related concepts does not come from the research literature* *The key/related concept distinction here is not, as far as we can tell, derived from the literature. But it may here be a useful way of bringing together a focus on disciplines and an interdisciplinary approach.*
2 Concepts are generally defined as mental representations of categories of objects, events, or other entities. They are thus abstractions and have also been called "enduring understandings", "essential understandings", and "Big Ideas", terms which tend to be used synonymously in the literature.	Concepts are powerful, broad and abstract organizing ideas that may be transdisciplinary or subject-based (1) Students will demonstrate knowledge and understanding of the concepts, methods and elements of … drama, … including using specialized language (2) The continuums make explicit the conceptual understandings that are being developed at each phase. The development of	*Adds the transdisciplinary angle* *The assumption is that "concepts, methods and elements" are different but the document doesn't clarify how* *The document defines what it means by learning outcomes but there is no comparable definition of 'conceptual understandings'.*

	these understandings is supported by the learning outcomes associated with each phase (2) A concept is a "big idea"—a principle or notion that is enduring, the significance of which goes beyond particular origins, subject matter, or place in time (3) A concept is a big idea—a principle or conception that is enduring, the significance of which goes beyond aspects such as particular origins, subject matter or place in time (5)	*For example, in the continuum for Responding phase 3, one conceptual understanding is given as "People explore issues, beliefs and values through art" and a learning outcome for Drama at the same phase is given as "consider the composition of an audience when preparing an effective formal and/or informal presentation". It is not clear why one of these is a conceptual understanding but the other is not. This does become clearer in the Creating continuum as the learning outcome verbs tend to be action whereas the conceptual understandings are expressed in thinking/feeling verbs.* *It is not clear that a concept has to be an 'enduring' principle. The literature refers to 'enduring understandings'* *Consistent with the definition in MYP.*
3 Concepts vary in terms of their level of abstraction and/or universality, from everyday concepts, low-level or microconcepts, to key concepts, high-level or macroconcepts. It is important that some emphasis be given in teaching to the more over-arching concepts rather than trying to cover lots of material in a superficial way.	Key concepts provide a lens for conceptual understandings within a transdisciplinary unit of inquiry; related concepts provide a lens for conceptual understandings within a specific subject (1) Concepts represent ideas that are broad, abstract, timeless and universal. (1) Key concepts drive learning experiences and help to	*Distinction between key and related concepts is unusual* *Literature tells us that concepts vary in terms of universality and hence timelessness* *Literature suggests giving some emphasis to teaching of higher level concepts.*

	frame a unit of inquiry. By identifying and investigating key concepts, students learn to think critically about big ideas.(1)	
6 Concepts develop spontaneously as children experience the world and try to make sense of it. Schooling needs to build upon these spontaneous concepts by deliberately introducing learners to a wider range of scientific/academic concepts that they probably would not develop simply through personal life experiences.	Young students come to school with their own experiences, theories and capabilities. While a student's prior knowledge may align with the subjects identified by the PYP, young students do not experience the world through these lenses. Instead, they learn from their environments, people around them, seeing experts at work, questioning and reflection, with little need for specific knowledge instruction (1)	*Teachers build upon this previous experience*
7 Children's concepts are generally localised to a particular area of expertise and may not generalise to other areas without deliberate prompting.	Concepts help to build understandings across, between and beyond subjects (1) Concepts place no limits on breadth of knowledge or on depth of understanding, and therefore are accessible to every student (1) Curriculum … promotes conceptual understanding and knowledge transferable to new contexts (5)	*This may happen but it seems not to be universal* *Concepts may not actually generalize unless deliberate prompted* *Transference may not be as simple as this.*
8 Crucial to the development of scientific/academic concepts is helping arouse the learner's conscious awareness of a concept, thus assisting generalizability across subjects/situations.	The exploration and re-exploration of concepts lead students towards engagement with complex ideas, including the ability to transfer and apply ideas and skills to new situations (5)	*Needs more deliberate focus on transfer, including raising students' conscious awareness*
12 Students learn best when: 7. concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general; 8. concepts are learned in the process of solving authentic problems rather than when pieces of information are presented as isolated facts to be learned;	As PYP teachers become familiar with concepts and conceptual understandings, they identify authentic links between subjects and within the programme of inquiry. Single-subject teachers and support teachers connect learning through the programme of inquiry's central ideas wherever the learning is authentic (1)	*Authenticity is a key feature of effective concept learning*

9. the difficulty of a task meets student capabilities.		
17 The big ideas of a subject take the form of concepts and generalisations which help learners manage and make sense of the massive amount of information they encounter in subjects. Such categorisations function as "hooks" on which learners can "hang" new information.	They learn to recognize patterns and see the connections between discrete examples to strengthen conceptual understandings (1) Concepts represent the vehicle for students' inquiry into issues and ideas of personal, local and global significance, providing the means by which the essence of a subject can be explored.(5) Students understand when they build connections between the 'new' knowledge to be gained and their prior knowledge. More specifically, the incoming knowledge is integrated with existing schemas and cognitive frameworks. Since concepts are the building blocks for these schemas and frameworks, conceptual knowledge provides a basis for understanding (5)	*Using concepts to organize new information*
20 Key features of effective concept-based teaching models include recognising that both facts and concepts are essential elements of curriculum, and that learning is at its most effective when organised as a collaborative activity.	Students co-construct beliefs and mental models about how the world works based on their experiences and prior learning (1) DP courses are based on an interrelationship of concepts, content and skills all viewed as equally critical to student learning. Content is critical to building conceptual understanding. Concepts are made concrete through content. Skills give access to conceptual understanding and allow students to actively engage with content.(5).	*Learning seen as collaborative activity* *This a reference to the influence of Erickson's synergy*
23 Teachers ask a great many questions in lessons but need to consider varying the types of questions, to	Carefully crafted questions, wonderings and provocations stimulate critical-thinking skills (1)	*Key importance of teacher questioning*

include not just factual questions, which focus on content that students need to know, but also conceptual questions, which connect this factual content with the concepts which underpin it, and open questions, designed to provoke thought and discussion.		
25 Active learning pedagogies have been shown to improve student conceptual understanding and involve students actively reflecting upon what they are learning.	Arts in the PYP exemplify learning through inquiry because of the emphasis on, and the nature of, the creative process. The school's programme of inquiry provides a relevant and authentic context for students to create and respond to arts. Wherever possible, arts should be taught through the units of inquiry and should support students' inquiries. teachers have a responsibility to help students to make explicit connections between different aspects of their learning. Students need opportunities to identify and reflect on "big ideas" within and between the arts strands, the programme of inquiry, and other subject areas. The role of inquiry in arts is important as students engage in building understanding of these links and arts in the world.(2) Teachers and students use statements of inquiry to help them identify factual, conceptual and debatable inquiry questions. Inquiry questions give direction to teaching and learning, and they help to organize and sequence learning experiences.(3)	*The three Arts-focused documents (PYP Arts scope and sequence, MYP Arts Guide and DP Theatre Guide) each place a good deal of emphasis upon inquiry-led learning, with rather less explicit reference to concept-based teaching. In the PYP, the recommendation is that, "Wherever possible, arts should be taught through the units of inquiry and should support students' inquiries" (p.2), even though it is recognized that this may not always be possible.* *The MYP Arts Guide reinforces this by its recommendation that "teachers and students use statements of inquiry to help them identify factual, conceptual and debatable inquiry questions. Inquiry questions give direction to teaching and learning, and they help to organize and sequence learning experiences" (p. 26). It seems that, as with the PYP, conceptual learning and inquiry-led learning are seen to go hand in hand.*

	There is a reference to the 6 approaches to teaching, i.e. teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment. Otherwise CBTL is not referred to in this document. (6)	*This emphasis loses some force at DP level. The DP Theatre Guide refers to the six approaches to teaching, i.e. teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment (p. 4) and is imbued throughout with an emphasis upon inquiry as a basis for learning. But CBTL is scarcely referred to in this document, perhaps as a result of the increasing emphasis upon disciplinarity at this level.*
27 Students' answers in tests of examinations may not show their underlying understandings in areas of knowledge. A taxonomy of understanding (e.g. the SOLO taxonomy) may be a better tool for this.	The structure of observed learning outcomes (SOLO) taxonomy (Biggs and Collis 1982) outlines five levels of thinking: one level where students have no prior knowledge or understanding, two surface levels of knowledge and two deeper levels of thinking (conceptual understandings) (1)	*Use taxonomies to develop rubrics and assessment tasks to move beyond traditional examination tests*
28 A single testing instrument is unlikely to be sufficient for summative or formative assessment. A range of tools are necessary.	Highly effective assessment is authentic: It supports making connections to the real world to promote student engagement. And varied: It uses a wider range of tools and strategies that are fit for purpose in order to build a well-rounded picture of student learning (1)	*A single testing instrument is clearly unable to achieve all these things.*
32 Teachers can detect changes in learners' conceptual understandings by looking for key indicators, namely when: • the level of their understanding and use of abstract concepts increases; • they make connections between multiple concepts; • they apply and transfer their understandings to more complex and distant contexts as	Progress in conceptual understandings is evident when the use of abstract concepts increases, connections are made between multiple concepts to explore the central idea, understandings are transferred to more complex contexts, actions are informed and taken based on existing and new understandings of the central idea (1) The assessment criteria for Knowledge and	*Useful model of the purposes of assessment – implications for the form*

well as to those that are familiar; • they take responsible actions and make informed decisions that are based on their new understandings; • they begin to understand that concepts can have different interpretations.	Understanding centre around three statements: The student: i. demonstrates awareness of the art form studied, including use of appropriate language ii. demonstrates awareness of the relationship between the art form and its context iii. demonstrates awareness of the links between the knowledge acquired and artwork created. Progression is indicated by the use of either of the adjectives *limited*, *adequate*, *substantial* or *excellent* being attached to the word *awareness* in each of these statements (3).	 *There is no attempt to define what is meant exactly by these adjectives nor, as far as we can tell, any exemplification.*
33 One of the most effective assessment tools is the giving of feedback to students - "goal-oriented, actionable, personalized, timely, ongoing and consistent" feedback.	Feedback has been identified as one of the most effective teaching practices (Hattie, Timperley 2007) and should, therefore, form the core of assessment. Effective teacher feedback offers opportunities for reflection and action. It encourages learning adjustment, promotes continuous improvement and celebrates success (1)	*The role of feedback correctly identified*

Appendix 3: An annotated bibliography of key sources

Adesope, O. & Nesbit, J. (2013). Animated and static concept maps enhance learning from spoken narration. *Learning and Instruction*, 27, 1–10
An animated concept map represents verbal information in a spider diagram that changes over time. The goals of the experiment reported here were to evaluate the effects of presenting an animated concept map concurrently with semantically equivalent spoken narration. The study used a 2 × 2 factorial design in which an animation factor (animated vs. static) was crossed with a representation factor (concept map vs. text). Students (N = 140) were randomly assigned to study one of four presentations on the human nervous system. The dependent measures were tests of free recall, knowledge and transfer. The concept map groups significantly outperformed the text groups on free recall and transfer. The animated concept map group did not significantly outperform the static map group. The authors hypothesize that the animated concept map provided no advantage over the static concept map because participants in both conditions were able to use the spoken narrative to sequence their reading.

Adesope, O., Cavagnetto, A., Hunsu, N., Anguiano, C., & Lloyd, J. (2016). Comparative effects of computer-based concept maps, refutational texts, and expository texts on science learning. *Journal of Educational Computing Research*, 55(1), 1–24
This study used a between-subjects experimental design to examine the effects of three different computer-based instructional strategies (concept map, refutation text, and expository scientific text) on science learning. Concept maps are spider diagrams that show concepts as nodes and relationships among the concepts as labelled links. Refutational texts are designed specifically to elicit common misconceptions that learners typically hold about a particular topic, directly refute the misconceptions, and present scientific explanations as compelling alternatives. Expository scientific texts consist of texts that are written specifically to present correct scientific information. Sixty-seven participants were randomly assigned to study one of three computer-based presentations on climate change. The dependent measures were tests of free recall and transfer. The concept map group significantly outperformed the refutational and scientific text groups on both free recall and transfer tests. Practical and theoretical implications of these findings are discussed.

Ampartzaki, M. & Kalogiannakis, M. (2016) Astronomy in early childhood education: a concept-based approach. *Early Childhood Education Journal*, 44, 169-179
In an attempt to understand the natural world's phenomena, young children form their perceptions of different aspects of the macrocosm, which they contrast with new scientific concepts. This process calls for an early intervention that will provide the stimuli and the tools for the development of new concepts, ideas, and cognitive structures. The purpose of this present article was to present an instructional intervention for young children about the science of celestial bodies, with some reference to the pedagogical content knowledge of astronomy. A concept-based, multidisciplinary approach to developing curriculum activities was adopted and the content of activities placed particular emphasis on: (1) Spatial learning and spatial thinking, which are considered as central and fundamental to astronomy education, and (2) the alternation between the Earth-based and space-based perspectives of the shape, position, and movement of celestial bodies

Beyer, B. K., & Penna, A. N. (1971). Why teach concepts? In B. K. Beyer & A. N. Penna (Eds.), *Concepts in the social studie*s: Bulletin no 45. Washington: National Council for the Social Studies. Available: https://files.eric.ed.gov/fulltext/ED049151.pdf

These papers in this pamphlet were chosen to give practical, understandable answers to several questions concerning concept teaching. What are concepts? Why teach them? How can concepts be taught? What are the implications of teaching? Here concept teaching implies: 1) developing the learners' ability to conceptualize; 2) evolving more complex conceptualization; 3) teacher articulation of concepts, and being aware of previously learned concepts; 4) developing inquiry-teaching strategies; 5) evaluating teaching through the learners' concept application; and, 6) using many types of media and personal experiences. With changes in the framework of the traditional social studies classroom and curriculum using sequential topically organized courses or a spiral curriculum organization, a concept-oriented curriculum can be facilitated. It is necessary, however, to limit the number of concepts to be learned, and to limit the amount of content for the purpose of depth. In this way concept learning can be facilitated at any grade level.

Birbili, M. (2007). Making the case for a conceptually based curriculum in early childhood education. *Early Childhood Education Journal*, 35(2), 141–147. Available at (free login required):
https://www.researchgate.net/publication/225487736_Making_the_Case_for_a_Conceptually_Based_Curriculum_in_Early_Childhood_Education/download
The purpose of this paper is to make the case for organising teaching and learning in early childhood education around concepts and generalisations rather than inert facts. It is now widely accepted that facts alone are not enough to help children discern patterns and relationships, group things together, see big ideas and solve problems. Facts need to be placed in a conceptual framework to be understood and remembered. Teachers can facilitate concept development by putting concepts and generalisations (rather than facts) at the centre of activities, providing children with a wide variety of tangible experiences, helping them learn how to observe and represent what they see and hear and providing them with multiple examples of the concepts being taught.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academies Press.
In its second edition, *How People Learn* has been expanded to show how the theories and insights from the original book can translate into actions and practice, now making a real connection between classroom activities and learning behaviour. This edition includes far-reaching suggestions for research that could increase the impact that classroom teaching has on actual learning. The book offers exciting new research about the mind and the brain that provides answers to a number of compelling questions. When do infants begin to learn? How do experts learn and how is this different from non-experts? What can teachers and schools do-with curricula, classroom settings, and teaching methods--to help children learn most effectively? New evidence from many branches of science has significantly added to our understanding of what it means to know, from the neural processes that occur during learning to the influence of culture on what people see and absorb. *How People Learn* examines these findings and their implications for what we teach, how we teach it, and how we assess what our children learn. The book uses exemplary teaching to illustrate how approaches based on what we now know result in in-depth learning. This new knowledge calls into question concepts and practices firmly entrenched in our current education system. Topics include:
* How learning changes the physical structure of the brain.
* How existing knowledge affects what people notice and how they learn.
* The amazing learning potential of infants.
* The relationship of classroom learning to the everyday settings of community and workplace.
* A realistic look at the role of technology in education.

Brooks, B., Gilbuena, D., Krause, S. and Koretsky, M. (2014) Using Word Clouds for Fast, Formative Assessment of Students' Short Written Responses. *Chemical Engineering Education*, 48(4), 190-198
This article describes how word clouds can be used for formative assessment in active learning. It focused on the ways word clouds led to improved instruction through their use as a formative assessment tool that could provide teachers and students with valuable, timely feedback. The article illustrates the use of word clouds with evidence from two active-learning examples: student in-class responses to multiple-choice concept questions; and student responses to reflection exercises, intended to assess the most confusing topic or concept presented.

Brophy, J. (2001) (Ed.). Subject-specific instructional methods and activities. Advances in Research on Teaching, Vol. 8. New York: Elsevier. Available https://www.emeraldinsight.com/doi/book/10.1016/S1479-3687%282001%298
This book explores the tension between the search for generic principles of good teaching that cut across school subjects and the belief that best practices might differ in each subject. Its contributors all favour teaching in ways that encourage learners to learn each subject with an understanding of its big ideas, appreciation of its value, and a growing ability and willingness to apply it in their lives outside school. They discuss the curricular, instructional, and assessment practices that foster this kind of learning in fourteen school subjects, focusing on teaching methods and learning activities. In the introduction, the book presents twelve generic guidelines for good teaching that represent current thinking about best practices that should be applicable to any school subject. Chapters on particular school subjects (beginning reading, content area reading and literature studies, writing, number, geometry, biology, physics, chemistry, earth science, history, physical geography, cultural studies, citizenship education, and economics) synthesize current thinking about best practices in teaching each subject, commenting on the applicability of generic principles but focusing on subject-special goals and methods. These state-of-the-art contributions take into account not only relatively formal research, but also the wisdom of practice as represented in standards documents, case studies of good teaching, and the methods and activities commonly recommended in subject-specific teacher education texts.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Powell, J., Westbrook, A. & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs, CO: BSCS (Biological Sciences Curriculum Study). Available at: https://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Full_Report.pdf
This review centres on the BSCS 5E Instructional Model. That model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Since the late 1980s this instructional model has been used in the design of BSCS curriculum materials. The model describes a teaching sequence that can be used for entire programs, specific units, and individual lessons. The BSCS 5E Instructional Model plays a significant role in the curriculum development process as well as the enactment of curricular materials in science classrooms.

Chadwick, D. (2009) (Ed.) *Approaches to Building Conceptual Understandings*. Wellington, New Zealand: Ministry of Education. Available: http://ssol.tki.org.nz/Social-studies-years-1-10/Teaching-and-learning/effective_teaching_in_social_studies/Building-conceptual-understandings/Approaches-to-Building-Conceptual-Understandings-in-the-Social-Sciences
This book provides ideas and examples of how teachers can build learners' understanding of key social sciences concepts during the 5 – 15 years age span. It examines what concepts and conceptual understandings are, why they are important,

and how they can be developed in social studies. It provides some strategies and approaches for building conceptual understanding and considers the role of the inquiry process in developing those understandings. Assessing conceptual understandings and conceptual progression is also discussed, using examples drawn from the social studies exemplars.
A parallel volume extends to senior school work (age 15 to 18).

Chan, C., Tsui, M. & Chan, M. (2002). Applying the Structure of the Observed Learning Outcomes (SOLO) Taxonomy on Student's Learning Outcomes: an empirical study. *Assessment and Evaluation in Higher Education,* 27 (6), 511-527
This article explores the application of different educational taxonomies in measuring students' cognitive learning outcomes. The objectives were to compare three educational taxonomies—namely, the Structure of the Observed Learning Outcomes (SOLO) taxonomy, Bloom's taxonomy and the reflective thinking measurement model—and to test the application value of these taxonomies. A comparative literature review was conducted to provide an underlying conceptual framework. Recommendations from this review were examined experimentally. Scripts of long essay papers and short classroom discussion responses were analysed by use of the taxonomies. It was found that SOLO was suitable for measuring different kinds of learning outcomes. It is suggested that the next step of research should be on setting up panels of judges to find out which taxonomy is suitable for measuring what learning outcomes under which contexts.

Chang-Wathall, J. (2016). *Guiding Questions to Check for Math Understanding*. Corwin Connect, Sept 26th. Available http://corwin-connect.com/2016/09/guiding-questions-check-math-understanding/
Guiding questions are a vehicle to draw out conceptual understandings (generalizations) from learners. This paper suggests that there are three types of such questions: *Factual Questions* are the "what" questions, such as "What is the formula for the circumference of a circle?" Factual questions ask for definitions, formulae in symbolic form, and memorised vocabulary. Often factual questions begin with: What is…? *Conceptual questions* use the factual content in a unit of work as a foundation to ask students for evidence of conceptual understanding. Often conceptual questions start with: How or why…? *Debatable or provocative questions* create curiosity and debate and provoke a deeper level of thinking. For example, for a unit on circles a debatable or provocative question could be: Is a circle a polygon?

Cousin, G. (2006) An introduction to threshold concepts, *Planet* No 17, December 2006, pp 4-5. doi.org/10.11120/plan.2006.00170004

The idea of threshold concepts emerged from a UK national research project into the possible characteristics of strong teaching and learning environments in the disciplines for undergraduate education. In pursuing this research in the field of economics, it became clear to Meyer and Land that certain concepts were held by economists to be central to the mastery of their subject. These concepts, Meyer and Land argued, could be described as 'threshold' ones because they had certain features in common. The purpose of this brief piece was to outline these features and to point to the distinctive value of a threshold concept approach for curriculum design.

Daley, B. & Torre, D. (2010). Concept maps in medical education: An analytical literature review. *Medical Education*, 44, 440–448
Various authors have acknowledged the need for alternative teaching and learning strategies that will enable students to retain vast amounts of information, integrate critical thinking skills and solve a range of complex problems. Previous research has indicated that concept maps may be one such teaching and learning strategy. This article

aims to: (i) review the current research on concept maps as a potential pedagogical approach to student learning, and (ii) discuss implications for student teaching and learning, as well as directions for future research. The review provides ideas for teachers on the use of concept maps in teaching and learning. Strategies such as fostering critical thinking and reasoning, incorporating concept mapping within problem-based learning, and using concept mapping in group and collaborative learning are identified.

Dell'Olio, J. M., & Donk, T. (2007). *Models of teaching. Connecting student learning with standards*. Thousand Oaks, CA: Sage
A key feature of this book is its presentation of some classic and contemporary models of teaching appropriate to primary and secondary settings. It uses detailed case studies to discuss 10 models of teaching and to show how they can be connected to various standards and benchmarks. This book provides readers with theoretical and practical understandings of how to use models of teaching to both meet and exceed the growing expectations for research based instructional practices and student achievement. At the core of the book are 10 chapters, each introducing a classic and contemporary model of teaching. Each is illustrated with two detailed case studies that demonstrate the introduction and application of the models in classroom settings after which the reader is invited to reflect on the pedagogic moves these teachers considered as they planned each lesson and their opinions of the success of each lesson.

Dexter, D. D., Park, Y. J., & Hughes, C. A. (2011). A meta-analytic review of graphic organizers and science instruction for adolescents with learning disabilities: Implications for the intermediate and secondary science classroom. *Learning Disabilities Research & Practice*, 26(4), 204-213
This article presents a meta-analysis of experimental and quasi-experimental studies in which intermediate and secondary students with learning disabilities were taught science content through the use of graphic organizers. Following an exhaustive search for studies meeting specified selection criteria, 23 standardized mean effect sizes were extracted from six articles involving 271 participants in grades 6 through 12. Findings included that the use of graphic organizers was associated with increased vocabulary knowledge and factual comprehension measured by multiple-choice tests in science. Conclusions, implications for future research, and practical recommendations are presented.

Dickman, N. E. (2009). The challenge of asking engaging questions. *Currents in Teaching and Learning*, 2(1), 316
This paper explores the uses of questions in the classroom, and isolates a unique kind of question, the "question-eliciting-question" (or QEQ), that poses a challenge for teachers leading classroom discussions. Research shows that teachers spend large portions of their classroom time asking questions. While pedagogical theory promotes the use of "higher-order" questions because they purportedly promote complex and critical thinking, the questions teachers ask in practice rarely fulfil this goal. Part of the problem is the way we have come to think about questions and the normative uses we make of them. They are essentially, the paper argues, commands. Commands demand mere answers. QEQs, however, are not something to be answered, but to be shared and discussed.

Douglas, K. H., Ayres, K. M., Langone, J., & Bramlett, V. B. (2011). The effectiveness of electronic text and pictorial graphic organizers to improve comprehension related to functional skills. *Journal of Special Education Technology*, 26(1), 43-56
This study evaluated the effects of a computer-based teaching program to assist three students with mild to moderate intellectual disabilities in using pictorial graphic organizers as aids for increasing comprehension of electronic text-based recipes. Student comprehension of recipes was measured by their ability to verbally retell recipe steps

with their graphic organizer. Students' ability to follow a novel recipe with the assistance of a pictorial graphic organizer tested generalization and authentic use of the recipes. All students improved their comprehension related to the e-text presentation of recipes after the introduction of graphic organizers, and performance generalized to the novel recipes and actual food preparation. Results of the investigation are discussed in the context of integrating graphic organizers into the curriculum and technology-enhanced text-based activities.

Edmonson, K. (2005). Assessing science understanding through concept maps. In Mintzes, J., Wandersee, J. & Novak, J. (Eds.). *Assessing science understanding: A human constructivist view* (19-40). Burlington, MA: Elsevier Academic Press
This paper focuses on the importance of concept maps for effectively teaching science students. Students who learn meaningfully relate information from different sources in an attempt to integrate what they learn with the intention of imposing meaning. They form connections between new information and material that has been previously studied, and they think about the underlying structure of what is learned. Concept maps have been particularly helpful in representing aspects of students' learning. They may also be used by students as a study tool or by teachers to evaluate learning, enhance teaching, or facilitate curriculum planning. Concept mapping is a tool for representing the interrelationships among concepts in an integrated, hierarchical manner. Concept maps depict the structure of knowledge in statements that dictate the relationships among the concepts in a map. Concept maps provide a useful approach for promoting and assessing meaningful learning by providing a tangible record of conceptual understanding. Not only are concept maps useful for determining whether, or to what extent, shared meaning has occurred, but they also portray the areas where it has not been achieved.

Erickson, H. L. (2012). *Concept-based teaching and learning. IB position paper*. The Hague: International Baccalaureate Organisation. Retrieved from http://www.ibmidatlantic.org/Concept_Based_Teaching_Learning.pdf
This paper examines the characteristics of concept-based curriculum and instructional models and identifies the International Baccalaureate (IB) programmes as a three-dimensional, concept-based model. A discussion of the benefits of concept-based instruction supports the majority of attributes in the IB learner profile. Concept-based instruction requires an understanding of synergistic thinking, transfer of knowledge and social construction of knowledge. This paper addresses these areas and discusses them in the context of the required IB pedagogy. It concludes with a review of the challenges in implementing a concept-based model and a summary of the rewards.

Erickson, H. L., (2008). *Stirring the Head, Heart, and Soul: Redefining Curriculum, Instruction, and Concept-Based Learning*. Thousand Oaks, CA: Corwin Press
(See also: Erickson, H. L., (2002). *Concept-based Curriculum and Instruction: Teaching Beyond the Facts*. Thousand Oaks, CA: Corwin press
and Erickson, H. L. (2007). *Concept-based curriculum and instruction for the thinking classroom*. Thousand Oaks, CA: Corwin Press)
This is the third volume in Lynn Erickson's trilogy of books on the topic of CBTL. It is a highly popular guide to curriculum design for quality teaching, providing a practical structure, a range of planning tools, and many classroom examples of effective curriculum strategies. This volume covers a wide range of topics, including: - Concept-based instruction - Aligning local curriculum with state and national content standards - Brain-based teaching methods - Higher-order thinking skills - Assessing and reporting student progress - Creating a life-long love of learning.

Fair, C. (2014) *A Qualitative Phenomenological Study of the Implementation of Concept-Based Instruction*. Unpublished Doctoral thesis, University of Phoenix, USA
The purpose of this study was to explore the experiences of 8 secondary teachers who received professional development and implemented concept-based instruction (CBI). The study revealed (a) teachers' perceptions of the adequacy of professional development, (b) teachers' self-assessments of progress in implementing CBI, (c) teachers' perceptions of consistency in implementation across classrooms, and (d) supports and barriers that influenced the implementation of CBI. Study participants recognized CBI as the basis for the organization and structure of the lessons used to promote understanding around concepts. The study findings indicate that the degree of implementation of CBI depended on individual understanding and the level of priority to use CBI recognized by school leadership. Recommendations suggest the need for comprehensive professional development design to support teacher implementation of new teaching strategies.

Finn, B., Thomas, R. & Rawson, K. (2018) Learning more from feedback: Elaborating feedback with examples enhances concept learning. *Learning and Instruction*, 54, 104-113
Two experiments investigated whether elaborating -test feedback with conceptual examples could increase conceptual understanding. In this study, participants studied psychology terms and definitions. During the practice phase, the definition was presented and participants attempted to recall the corresponding concept term. Immediately after responding, half of the participants were given feedback that provided the correct term. The other half was shown the correct term, followed by presentation of a concept example. Final test results suggested that presentation of examples during feedback bolstered performance across all test types and formats.

Gallavan, N. P., & Kottler, E. (2007). Eight types of graphic organizers for empowering social studies students and teachers. *The Social Studies*, 98(3), 117–128
Graphic organizers offer visual models that equip teachers and students with tools, concepts, and language to organize, understand, and apply information. Many teachers, concerned that social studies tends to overwhelm students, feel it is viewed as a complex and confusing subject unrelated to the contemporary world. Graphic organizers help students sort, show relationships, make meaning, and manage data quickly and easily before, during, and after reading and discussion. They are useful for reading difficult material, highlighting information, valuing cultural diversity, meeting needs of special populations, and supporting language learning. In this article, the authors present eight types of graphic organizers with descriptions, vocabulary, and examples applicable to citizenship and government, economics, geography, and history in pre-K-12 settings.

Gonzalez, J. (2017) The Great and Powerful Graphic Organizer. *The Cult of Pedagogy*. Available: https://www.cultofpedagogy.com/graphic-organizer/
This paper explores the use of the simple teaching tool: the graphic organizer. It looks at why graphic organizers are so powerful, explores some ways to use them that teachers may not have tried, and considers a few important tips for using them with the greatest impact.

Gütl, C. & García-barrios, V. (2005) The Application of Concepts for Learning and Teaching. In Auer, M. & Auer, U. (Eds) *Proceedings of the International Conference on Interactive Computer-Aided Learning*. Villach, Austria: Carinthia Technology Institute
Human-beings tend to simplify, unify and cluster characteristics in phenomena by concepts as well as interrelating them in order to build a knowledge structure for their

thoughts and notions. This paper focuses on the application of concepts in the field of learning and teaching. Firstly, possible application fields as well as interesting research and development are presented. Secondly, an overview is given of research and development work regarding the usage of conceptual spaces for e-learning.

Hall, T., & Strangman, N. (2008). *Graphic organizers*. Wakefield, MA: National Center on Accessing the General Curriculum. Available at: https://www.northernhighlands.org/cms/lib5/nj01000179/centricity/domain/18/graphic_organizers_2008.pdf
One way to help make a curriculum more supportive of students and teachers is to incorporate graphic organizers. Graphic organizers come in many varieties and have been widely researched for their effectiveness in improving learning outcomes for various students. The sections of this paper present a definition of graphic organizers, a sampling of different types and their applications, a discussion of the research evidence for their effectiveness, useful Web resources, and a list of referenced research articles.

Hmelo-Silver, C. (2004) Problem-based learning: What and how do students learn? *Education Psychology Review*. 16: 235–266
Problem-based approaches to learning have a long history of advocating experience-based education. Psychological research and theory suggest that if students learn through the experience of solving problems, they can learn both content and thinking strategies. Problem-based learning (PBL) is an instructional method in which students learn through facilitated problem solving. In PBL, student learning centres on a complex problem that does not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning and then apply their new knowledge to the problem and reflect on what they learned and the effectiveness of the strategies employed. The teacher acts to facilitate the learning process rather than to provide knowledge. This article discusses the nature of learning in PBL and examines the empirical evidence supporting it. The evidence suggests that PBL is an instructional approach that offers the potential to help students develop flexible understanding and lifelong learning skills.

Hwang, G., Kuo, F., Chen, N. & Ho, H. (2014) Effects of an integrated concept mapping and web-based problem-solving approach on students' learning achievements, perceptions and cognitive loads. *Computers and Education*, 71, 77-86
Although many students can search the World Wide Web with keywords and then select web pages related to a core topic, summarizing or organizing the retrieved information remains a difficult task for them. To address the problem, an integrated concept mapping and web-based problem-solving environment was developed and a study carried out to evaluate the effectiveness of the approach in terms of students' learning, satisfaction and cognitive load in an elementary school social studies course. The results suggest that the concept map-integrated approach can significantly enhance the students' web-based problem-solving performance, although the students showed lower degrees of technology acceptance and learning satisfaction in comparison with the conventional web-based problem-solving approach. The paper concludes that the integrated concept mapping and web-based problem-solving approach was helpful to students in guiding them to learn in a more effective way, although more needed to be done to make this approach satisfying for the students.

Hwee-Hwang, S. (2016). Conceptual teaching in primary social studies: Teaching the primary three reader, "Making the Little Red Dot blue and brown" in a conceptual way. *HSSE Online*, 5(2), 68-79. Available: http://www.hsseonline.edu.sg/journal/volume-5-issue-2- 2016/conceptual-teaching-primary-social-studies-teaching-primary-three

This paper looks at what conceptual teaching involves, the differences between conceptual and traditional teaching and the advantages of conceptual teaching. Different deductive and inductive approaches for teaching the big ideas of subject matter, that is, the concepts and generalisations, are described. The paper also focuses on the teaching of the primary three social studies reader entitled, "Making the Little Red Dot Blue and Brown" using some of the conceptual teaching approaches mentioned. The paper concludes with the importance of teacher subject matter knowledge in conceptual teaching.

Ilter, I. (2017) Concept-Teaching Practices in Social Studies Classrooms: Teacher Support for Enhancing the Development of Students' Vocabulary. *Educational Sciences: Theory and Practice*, 17(4), 1135-1164
The purpose of the study reported here was to describe social studies teachers' perceptions of their practices in teaching concepts within the context of social studies instruction in order to enhance students' vocabulary development in their classes. The study focused on how students' breadth and depth of vocabulary knowledge was supported by teachers' experiences and their self-reported practices in relation to teaching social studies content. A semi-structured interview form was used to determine teachers' perceptions and viewpoints. Results suggest that the teachers' practices for enhancing social studies vocabulary and for assessing its overall development supported widely accepted understanding and ideas about effective concept teaching. Some examples of these practices and assessment measures included interactive word-walls, contextualized vocabulary instruction, word analogy, semantic maps, vocabulary self-collection strategy, and concept circles.

Jonasson, D. (2006) On the Role of Concepts in Learning and Instructional Design. *Educational Technology Research and Development*, 54(2), 177–196
The field of instructional design has traditionally treated concepts as discrete learning outcomes. Theoretically, learning concepts requires correctly isolating and applying attributes of specific objects into their correct categories. Similarity views of concept learning are unable to account for all of the rules governing concept formation, patterns of concepts, and concepts-in-use. Probabilistic-prototype and exemplar views have accommodated some of the inherent fuzziness of concepts. Concepts can only be fully understood as processes of conceptual change, the reorganization of conceptual frameworks. Although very little research has focused on assessing conceptual change, the theories of conceptual change recommend assessing patterns of concepts and concepts-in-use. Descriptions of pertinent assessment methods are presented

Kapici, H., Akcay, H. & Yager, R. (2017) Comparison of Science-Technology-Society Approach and Textbook Oriented Instruction on Students' Abilities to Apply Science Concepts. *International Journal of Progressive Education*, 13(2), 18-28
It is important for students to learn concepts and to use them for solving problems and further learning. The aim of this study was to investigate students' abilities to apply science concepts that they had learned through the Science-Technology-Society based approach or through textbook-based teaching. Science classes were designed based on the STS approach for 301 students (experimental group) and textbook-based teaching was used with 308 students (control group). The students were aged from 12 to 15 and the teaching took place over one semester. The results showed that the STS students were better able to meaningfully apply basic science concepts to new situations than the students who were taught using textbooks.

Kim, P., & Olaciregui, C. (2008). The effects of a concept map-based information display in an electronic portfolio system on information processing and retention in a fifth-grade science class covering the Earth's atmosphere. *British Journal of Educational Technology*, 39(4), 700–714

An electronic portfolio system was tested in a fifth-grade science class. The control-group students accessed a traditional folder-based information display in the system and the experimental-group students accessed a concept map-based information display to review a science portfolio. The student-constructed science portfolio was a result of a collection of digital artefacts such as graphic images, instructional videos and textual files on terms and definitions relevant to the Earth's atmosphere. In the information-processing performance test, the experimental-group students scored significantly higher and spent much less time in finding answers to the questions presented.

Kinchin, I. (2014) Concept Mapping as a Learning Tool in Higher Education: A Critical Analysis of Recent Reviews. *The Journal of Continuing Higher Education*, 62, 39–49
This article re-examined the conclusions drawn by analyses of the literature on concept mapping as an educational tool by considering the wider literature on curriculum development. As part of the review process, issues raised by previous analyses were reconsidered with reference to educational research papers that were not considered previously. A greater consideration of the context for learning provided alternatives to some of the assumptions that underpinned the discipline-specific concept mapping literature. The methodological shortcomings in the literature on concept mapping revealed by earlier reviews were re-evaluated to support reflection on how the tool may be profitably used and also how such reviews may be conducted to better inform practice. This article offers enhanced guidance on the contextualisation of concept mapping and recommendations for its future use in education.

Kinchin, I., Hay, D. & Adams, A. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research*, 42 (1), 43-57
This paper describes a qualitative approach to analysing students' concept maps. The classification highlights three major patterns which are referred to as 'spoke', 'chain' and 'net' structures. Examples are given from Year 8 science classes. The patterns are interpreted as being indicators of progressive levels of understanding. It is proposed that identification of these differences may help the classroom teacher to focus teaching for more effective learning and may be used as a basis for structuring groups in collaborative settings. This approach to analysing concept maps is of value because it suggests teaching approaches that help students integrate new knowledge and build upon their existing naïve concepts.

Kirschner, P., Sweller, J. and Clark, R. (2006) Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, 41(2), 75–86
Evidence for the superiority of guided instruction is explained in the context of our knowledge of human cognitive architecture, expert–novice differences, and cognitive load. Although unguided or minimally guided instructional approaches are very popular and intuitively appealing, the point is made that these approaches ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance. Recent developments in instructional research and instructional design models that support guidance during instruction are briefly described.

Lai, W. (2012). *Concept-Based Foreign Language Pedagogy: Teaching the Chinese Temporal System*. Unpublished doctoral thesis, Pennsylvania State University, USA

The dissertation reports an investigation of the effect of a concept-based approach to teaching the Chinese temporal system to English-speaking university learners. Concept-based instruction provided learners with the meaning of the target grammatical unit, and provided step-by-step guidance for learners to develop their understanding of this. The performance on written tasks (translation and essay) suggested that the experimental group outperformed the control group and that a coherent and organized pedagogical presentation could enhance learners' development. In addition, complicated grammatical concepts regarded as more suitable for advanced learners could be taught to novice learners when the concepts were presented as meaningful units in a coherent and systematic way.

Little, C. (2017). Designing and Implementing Concept-Based Curriculum. In Tan, L. (Ed.) *Curriculum for High Ability Learners* (43-59). Singapore: Springer Nature

Given our enhanced access to information through the ever-increasing capacity of the informational tools readily available, the role of schools becomes much more about helping students find and make sense of information than of delivering it. Within this context, an approach to curriculum and instruction that focuses on the delivery and retention of facts is neither practical nor productive. A concept-based approach to curriculum and instruction organises the learning experience more around meaning-making and the learner's ability to sort, integrate, and transfer understanding in multiple contexts. Several research studies comparing conceptually oriented curricula with more traditional approaches have demonstrated that students working with a conceptual focus learn the content just as well as or better than their peers in comparison classes, while outperforming those peers in measures of critical and conceptual thinking. This chapter briefly addresses some of the rationale and benefits of a concept based approach to curriculum and then turns to consideration of some of the issues and challenges presented by such an approach, along with some recommendations for ways of addressing these issues and challenges.

Liu, P., Chen, C. & Chang, Y. (2010). Effects of a computer-assisted concept mapping learning strategy on EFL college students' English reading comprehension. *Computers and Education*, 54(2), 436–445

The purpose of this study was to investigate the effects of a computer-assisted concept mapping learning strategy on EFL college learners' English reading comprehension. The research questions were: (1) what was the influence of the computer-assisted concept mapping learning strategy on different learners' English reading comprehension? (2) did the computer-assisted concept mapping learning strategy affect learners' use of other English reading strategies? One hundred ninety-four students who were enrolled in the English course were divided into low-level and high-level groups according to their English proficiency. A computer-assisted concept mapping learning strategy was introduced to the learners in the experimental class to improve their reading ability. It was found that the computer-assisted concept mapping learning strategy had greater reading benefit for the low-level group than for the high-level group. It also emerged that the computer-assisted concept mapping learning strategy enhanced learners' use of other English reading strategies–listing, enforcing, and reviewing.

Mayer, R. E. (2007). *Learning and instruction*. Upper Saddle River, NJ: Prentice Hall.

The purpose of this book is to answer the key questions - How do people learn? How can teaching promote learning? The author focuses on the big ideas, preferring that readers understand a few exemplary ideas deeply, rather than numerous ideas superficially. The book is research-based and painstakingly shows how specific pedagogic implications follow from research and theory. Coverage is organized around the two sides of the educational coin, learning in subject areas and teaching methods that foster meaningful

learning. The text uses clear definitions, concrete examples, active learning tasks and a conversational writing style that easily engages readers by addressing them directly.

Mbajiorgu, N. M. & Ali, A. (2003). Relationship between STS approach, science literacy and achievement in biology. *Science Education*, 87(1), 31-39
This study aimed to investigate the relationship between the Science-Technology-Society (STS) approach, scientific literacy, and achievement in biology. The STS approach focuses on setting science education in real world problems, thus asking learners to apply science knowledge and concepts to the world around them. Four secondary schools, eight teachers, and 246 students were involved in the study. Two classes were randomly selected from each school and assigned to either the experimental or control group. The results showed a weak positive relationship between scientific literacy and achievement in biology for the experimental group and a no relationship for the control group. However, use of the STS approach seemed to lead to slightly stronger significant positive relationship. The conclusion was that STS approach might have affected other variables in the science classroom that in turn affected achievement in science.

McClure, J., Sonak, B. & Suen, H. (1999). Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. *Journal of Research in Science Teaching*, 36(4), 475 –492
The characteristics and practicality of concept mapping as a technique for classroom assessment were evaluated. Subjects received training in concept mapping techniques and were given a list of terms and asked to produce a concept map. The list of terms was from a course in which they were enrolled. The maps were scored and compared to a master map. The times required to provide training in concept mapping, produce concepts, and score concept maps were compatible with the adoption of concept mapping as classroom assessment technique.

McCoy, J. D., & Ketterlin-Geller, L. R. (2004). Rethinking instructional delivery for diverse populations: Serving all learners with concept-based instruction. *Intervention in School and Clinic,* 40(2), 8895
When students come into subject classes with below average reading, it can be challenging for teachers to teach complex material, and students may study facts without grasping the larger concepts. Research has suggested that if the teacher takes responsibility for identifying and explaining the key concepts within course materials, both of these difficulties can be overcome. Overt identification of concepts and their characteristics and the deliberate use of graphic organizers can reduce the reading comprehension demands placed on students with low abilities.

McNaught, C., and Lam, P. (2010) Using Wordle As a Supplementary Research Tool. *The Qualitative Report*, 15(3), 630-43. Available: https://nsuworks.nova.edu/tqr/vol15/iss3/8/
A word cloud is a special visualization of text in which the more frequently used words are effectively highlighted by occupying more prominence in the representation. Wordle is a software tool for producing such word clouds from samples of text. This article describes how Wordle was used to produce word-cloud analyses of the spoken and written responses of informants in two research projects. Word clouds can be a useful tool for preliminary analysis and for validation of previous findings. However, although Wordle is a useful tool it may not be suitable to be used as a stand-alone research tool comparable to traditional content analysis methods.

McTighe, J. & Seiff, E. (undated) *A Summary of Underlying Theory and Research Base for Understanding by Design*. Available https://www.jaymctighe.com/wp-content/uploads/2011/04/UbD-Research-Base.pdf
Understanding by Design (UbD) is a framework for improving student achievement through curriculum development, instructional design, assessment, and professional

development. It is based on some key ideas, including: 1. A primary goal of education is the development and deepening of student understanding. 2. Evidence of student understanding is revealed when students apply knowledge and skills within authentic contexts. 3. Teachers provide opportunities for students to explain, interpret, apply, shift perspective, empathize, and self-assess. The aim of this paper is to answer two key questions about UbD: a) What is the research base underlying Understanding by Design? And b) How do we know that Understanding by Design, when appropriately applied, will enhance student achievement? The principles and practices of UbD reflect contemporary views of learning based on research in cognitive psychology and are validated by specific studies of factors influencing student achievement. A number of sources providing the underlying research base for UbD are summarized in this paper.

Meyer, E. & Land, R. (2003) *Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines*. Occasional Report 4, ETL Project. Edinburgh: University of Edinburgh.
http://www.leeds.ac.uk/educol/documents/142206.pdf
This report arose from the research of the 'Enhancing Teaching and Learning Environments in Undergraduate Courses' (ETL) Project. The ETL Project was seeking to identify factors leading to high quality learning environments within five disciplinary contexts across a range of higher education institutions. Meyer's notion of a threshold concept was introduced into project discussions on learning outcomes as a particular basis for differentiating between core learning outcomes that represented 'seeing things in a new way' and those that did not. A threshold concept was thus seen as something distinct within what university teachers would typically describe as 'core concepts'. Furthermore, threshold concepts may represent, or lead to troublesome knowledge – knowledge that was conceptually difficult, counter-intuitive or 'alien'. Drawing both on interviews and on observations contributed by academic colleagues from a range of disciplines, the report attempts to define the characteristics of threshold concepts.

Milligan, A., & Wood, B., 2010. Conceptual understanding as transition points: making sense of a complex social world, *Journal of Curriculum Studies*, 42(4), 487- 501
Teaching for conceptual understanding has been heralded as an effective approach within many curriculum frameworks internationally in an age of rapid and constant change around what counts as 'knowledge'. Drawing from research and experience within the social studies curriculum, this paper reflects on some of the largely unstated and unexplored aspects of adopting concept-based approaches to curriculum. The nature of learning within the social sciences highlights a society which is not static and factual, but instead, complex and diverse. This paper presents a number of reasons why teaching conceptual understandings as inert facts or 'end points' fails to prepare learners to understand and engage in a complex and rapidly changing social world. Instead, conceptual understandings must be understood as changeable, contextual, and contested. The paper considers how conceptual fluidity might be accommodated in teacher planning, arguing that conceptual understandings may more usefully be regarded as transition points in learning, rather than irrefutable destinations.

Morfidi, E., Mikropoulos, A. & Rogdak, A. (2018) Using concept mapping to improve poor readers' understanding of expository text. *Education and Information Technology.* 23: 271–28
The study reported in this paper examined whether the use of concept mapping was more effective in teaching content material in comparison to a traditional, lecture only, approach. Its objective was threefold. First, to determine if multimedia concept mapping produces differential learning outcomes compared to digital text-based concept mapping. Secondly, to compare the above experimental approaches to traditional teaching and to ascertain if there were significant differences in the level of satisfaction reported by children experiencing the three teaching approaches used. Thirty 10-11-year-old children

participated from which three groups of poor readers were formed, matched on age, gender and reading ability. The two experimental groups were taught with the use of digital text-based and multimedia concept maps respectively and the control group was subjected to the traditional teaching method using content reading material. The results indicated that concept mapping can be an effective means for teaching content. However, there were no differential learning outcomes when adding multimedia elements to concept maps. Moderate satisfaction was reported for all three approaches. The findings fit with the existing literature and emphasize the importance of concept mapping in the learning and instruction of children with reading difficulties.

Nair, C., Archana, J., Chatterjee, S. & Bijlani, K. (2015). Knowledge Representation and Assessment Using Concept Based Learning. *Proceedings of the 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*. 848-854. Available: ks/564ee39408ae4988a7a69527.pdf?inViewer=true&pdfJsDownload=true&disableCoverPage=true&origin=publication_detail
The process of learning can be improved with proper and timely feedback. This paper proposes a system that provides feedback for both teacher and student using concept-based learning. Various types of concepts are defined, and assessment is suggested for each concept. The level of knowledge acquired by students can be clearly represented using this approach. The feedback provided is goal-oriented, active, personalized, timely, ongoing and consistent, which counts for the novelty of this approach. Results from this study show that concept-based assessment and feedback motivates the students and helps them improve their examination scores.

Nair, S. & Narayanasamy, M. (2017). The Effects of Utilising the Concept Maps in Teaching History. *International Journal of Instruction* 10(3), 109-126
Many studies indicate that students are not particularly interested in learning History. This paper reports a study conducted to investigate the effects of utilizing the concept map method in the teaching of History in secondary schools. The researchers investigated whether the use of concept maps in the teaching of History helped the subjects from the experimental group to answer history questions better than the control group. The researchers also investigated whether this method helped to enhance students' interest in the learning of History. The findings suggest that the utilisation of the concept map method significantly improved students' achievement and interest in History. Findings of this study support the theory of meaningful learning and utilization of concept maps.

Nesbit, J., & Adesope, O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research*, 76(3), 413–448
This meta-analysis reviews studies in which students learned by constructing, modifying, or viewing node-link diagrams, or concept maps. 55 studies were included in the review, involving 5,818 participants. Students at levels ranging from Grade 4 to postsecondary used concept maps to learn in domains such as science, psychology, statistics, and nursing. Post-tests measured recall and transfer. Across several instructional conditions, settings, and methodological features, the use of concept maps was associated with increased knowledge retention. Mean effect sizes varied from small to large depending on how concept maps were used and on the type of comparison treatment.

Novak , J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press
For a very long time, educational theory and practice was influenced by the view of behavioural psychologists that learning was synonymous with behaviour change. In this book, the authors argue for an alternate view, that learning is synonymous with a change in the meaning of experience. They develop their theory of the conceptual nature of knowledge and describe classroom-tested strategies for helping students to construct

new and more powerful meanings and to integrate thinking, feeling, and acting. In their research, they found consistently that standard educational practices that did not lead learners to grasp the meaning of tasks usually failed to give them confidence in their abilities. It was essential to understand why and how new information is related to what one already knows. The book therefore gives a very useful background to Novak's seminal work on the use of concept maps in teaching and learning.

Novak, J. D. (2005). Results and implications of a 12-year longitudinal study of science concept learning. *Research in Science Education*, 35, 23-40
This paper describes the methods and outcomes of a 12-year longitudinal study into the effects of an early intervention program. The study began in order to challenge the idea that primary school children were either preoperational or concrete operational in their cognitive development and they could not learn abstract concepts. The paper describes the development and implementation of an audio tutorial science teaching sequence, and the tracing of that over 12 years, and of the children's conceptual understandings in science compared to a matched control group. During the study the concept map was developed as a new tool to trace children's conceptual development. We found that students in the experimental group far outperformed their counterparts, and this difference increased as they progressed through middle and high school. The data clearly support the earlier introduction of science instruction on basic science concepts and suggest that national curriculum standards for science grossly underestimate the learning capabilities of primary-age children.

Prince, M. (2004) Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*. 93(3), 223-231
This study examines the evidence for the effectiveness of active learning. It defines the common forms of active learning and critically examines the core element of each method. It suggests that there is broad but uneven support for the core elements of active, collaborative, cooperative and problem-based learning.

Ramsden, A. & Bate, A (2008) Using Word Clouds in Teaching and Learning
http://opus.bath.ac.uk/474/1/using%2520word%2520clouds%2520in%2520teaching%2520and%2520learning.pdf
The aim of this paper is to introduce the potential of using word clouds within teaching and learning. In particular, it addresses what a word cloud is, and what should be taken into consideration when using them and finally, compares different word cloud software. A word cloud is a visual depiction of words. The more frequent the word appears within the text being analysed the larger the word becomes. In essence a word cloud "plots" word frequency by the size of the word.

Reinhartz, J., & Van Cleaf, D. W. (1986). *Teach-practice-apply: The TPA instructional model, K-8*. Washington, D.C.: National Education Association
This little book explains the Teach-Practice-Apply (TPA) model for teaching. It begins with an overview of three general factors necessary for effective teaching: knowledge of the subject area; knowledge of teaching and learning theory; and the ability to select and use appropriate teaching strategies. A description is given of the components of the TPA. The Teach component is the part of a lesson that presents students with what they need to know. The Practice component of the lesson provides opportunities for students to "practice" what has been presented by completing work related to the lesson topic. In the Apply component of TPA, students begin to use the skill either with less teacher supervision or with teacher encouragement to use the skill in broader contexts. Discussions are given of how the TPA model may be used in student concept attainment, teacher demonstrations, problem solving, guided discussions, and simulations. The discussion of each teaching strategy is presented within the TPA format, and is accompanied by classroom examples. The final chapter examines how the TPA model can enhance student achievement, and offers suggestions for the teacher.

Ritchhart, R., Turner, T., & Hadar, L. (2009). Uncovering students’ thinking about thinking using concept maps. *Metacognition Learnin*g, 4, 145–159
A method for uncovering students’ thinking about their own thinking is explored within the context of an ongoing, multi-year intervention designed to promote the development of students’ thinking dispositions. The development of a concept-map instrument that classroom teachers could use and an analytic framework for interpreting students’ responses is presented. In a preliminary study, the concept map instrument was piloted to evaluate changes in students’ conceptions of thinking after a year’s participation in classrooms where their teachers actively sought to make thinking more visible. Concept maps from 239 students from grades 3 to 11 were analysed. Results suggest that the students’ conceptions of thinking had improved with age but also could be substantially developed through a classroom culture where thinking was modelled and where rich opportunities for thinking were present. The concept map instrument itself proved to be a robust instrument for uncovering students’ thinking about their thinking.

Roessger, K., Daley, B. & Hafez, D. (2018) Effects of teaching concept mapping using practice, feedback, and relational framing. *Learning and Instruction*, 54, 11-21
Although concept mapping is widely used in education, there is little research showing how best to teach it. The purpose of the research outlined in this paper was to investigate if practice and feedback could help improve students' concept mapping skills over time. Four online graduate courses at two universities were randomly assigned to one of two teaching conditions: a traditional concept map teaching strategy or traditional plus relational framing teaching strategy. Students in each course created three concept maps over three weeks following repeated teaching and feedback. Repeated practice and feedback improved the structural quality of students' concept maps, as well as the number of autobiographical elaborations within those maps. Relational scores in relational framing groups improved over time, whereas those in the traditional groups remained unchanged. Implications for teaching concept mapping are discussed.

Romero, C., Cazorla, M. & Buzon, O. (2017) Meaningful Learning Using Concept Maps as a Learning Strategy. *Journal of Technology and Science Education* 7(3): 313-332
This paper outlines the use of the concept map technique as a learning strategy in Science. Students were taught the technique and then independently created a concept map, applying what they had learned in the previous session. The resulting concept maps were evaluated, the grades obtained on assessment tests before the concept map experience compared to those obtained on the tests afterwards, and a survey conducted to find the level of student satisfaction about the teaching and the usefulness of the concept map technique. The results showed that more than 65% of students earned grades between 7 and 9.5 on the concept maps created independently. The study suggested that the students had learned how to create concept maps, and expressed a high level of satisfaction with the teaching they had received and the tool they had learned how to use.

Ruiz-Primo, M. A., Shavelson, R. J., Li, M., & Schultz, S. E. (2001). On the validity of cognitive interpretations of scores from alternative concept-mapping techniques. *Educational Assessment, 7*(2), 99-141
This paper describes concept maps as assessment tools for measuring one aspect of achievement, the organization of knowledge in a subject. Variations in tasks, response formats, and scoring systems produce different mapping techniques that may elicit different knowledge representations. The paper provides a framework to guide the research on the technical quality of this tool. It briefly describes some of the studies conducted and focuses on some of the dimensions that can be used to define the assessment task.

Rye, J., Landenberger, R. & Warner, T. (2013). Incorporating Concept Mapping in Project-Based Learning: Lessons from Watershed Investigations. *Journal of Science and Educational Technology* 22: 379–392
The concept map tool is underused in education, although research studies have supported the use of computer-based concept mapping applications in learning. This paper reports the outcomes of a professional development experience in which teachers applied computer-based concept mapping in project-based learning units that investigated local watersheds. Barriers to the adoption and use of concept mapping included technology access at the schools, lack of time for teachers to advance their technology skills, lack of student motivation to choose to learn, and student difficulty with linking terms. In addition to mitigating the aforementioned barriers, projects targeting teachers' use of technology tools may enhance adoption by recruiting teachers as partners from schools as well as a small number that already are proficient in the targeted technology and emphasizing the utility of the concept map as a planning tool.

Salomon, G., & Perkins, D. (1994). Transfer of Learning. In Postlethwaite, T. & Husen, T. (Eds), *International Encyclopedia of Education (2nd edition)*. Oxford, England: Pergamon Press
Transfer of learning occurs when learning in one context enhances (positive transfer) or undermines (negative transfer) a related performance in another context. Transfer includes near transfer (to closely related contexts and performances) and far transfer (to rather different contexts and performances). Transfer is crucial to education, which generally aspires to impact on contexts quite different from the context of learning. Research on transfer argues that very often transfer does not occur, especially ``far'' transfer. However, sometimes far transfer does occur. Findings from various sources suggest that transfer happens by way of two rather different mechanisms. Reflexive or low road transfer involves the triggering of well-practiced routines by stimulus conditions similar to those in the learning context. Mindful or high road transfer involves deliberate effortful abstraction and a search for connections. Conventional educational practices often fail to establish the conditions either for reflexive or mindful transfer. However, education can be designed to meet these conditions and achieve transfer.

Schill, B. & Howell, L. (2011) Concept-based Learning. *Science and Children*. 48 (6), 40-45
A major part of developing concept-based instruction is the use of an overarching idea to provide a conceptual lens through which students view the content of a particular subject. By using a conceptual lens to focus learning, students think at a much deeper level about the content and its facts (Erickson 2007). Using a conceptual lens also frames the learning in such a way that students are being asked to think and use language as a practitioner would in that discipline (Tomlinson et al. 2002). We used several steps in the process of developing our concept-based unit:

Stoddart, T., Abrams, R., Gasper, E., & Canaday, D. (2000). Concept maps as assessment in science inquiry learning – a report of methodology. *International Journal of Science Education*, 22(12), 1221 –1246
Increasing availability of technologies, such as CD ROMs and the World Wide Web, in schools means that more teachers have the potential to implement student-centred, inquiry-based approaches to learning. Assessing what each student knows in a broad subject area, such as science, is difficult. Assessing students' understanding in circumstances where each student may pursue different topics of study, where there is no way to predict in advance what those topics of study will be and where the possible topics of study include natural phenomena which are only beginning to be studied by professional scientists, is even more difficult. To meet the challenge of this, this paper discusses a way to assess student learning using an open-ended concept map activity

combined with a rubric which extracts quantitative information about the quality of understanding from each map.

Stoll, L., Fink, D., & Earl, L. (2003). *It's about learning (and it's about time): What's in it for schools?* London: RoutledgeFalmer
The purpose of this book is to focus attention in education on learning. Recent emphases have been on achieving standards through managing schools, teachers and the teaching process. But the real purpose of schools was, is, and always will be about learning. The authors argue that, in an increasingly complex, diverse and unpredictable world, it is necessary for schools and those working in them to refocus on learning at all levels - pupils, teachers, leaders, the organisation as a whole and all of the school's partners. The book contains a clear and well written discussion interleaved with practical examples and strategies.

Sunder, S. (2015) *Teacher Perceptions of the Development of One School's Own Concept-Based Curriculum Programme and its Intended and Unintended Outcomes: A Case Study of an International Baccalaureate World School in the United Arab Emirates*. Unpublished doctoral thesis, University of Bath, UK
This doctoral research study explored teacher perceptions about the development of a concept-based curriculum program, in the context of an International Baccalaureate (IB) World school, and the intended and unintended outcomes of the initiative. The study used data arising from analysis of curriculum documents, semi-structured interviews, and a web-based questionnaire completed by teachers. Findings revealed that, though teachers saw the experience of creating and delivering a conceptual curriculum as sometimes being challenging and frustrating, a vast majority preferred a flexible curriculum framework rather than a prescriptive curriculum. They enjoyed the freedom and flexibility of working with broad curricular frameworks but the lack of consensus amongst them on what counted as essential knowledge was often a matter of concern. Findings also showed that teachers saw the value and purpose in teaching for conceptual understanding, but this, when coupled with having to choose curriculum content and developing a coherent curriculum. made the experience both challenging and burdensome.

Talanquer, V. (2017). Concept Inventories: Predicting the Wrong Answer May Boost Performance. *Journal of Chemical Education*. 94, 1805 −1810
Several concept inventories have been developed to elicit students' alternative conceptions in chemistry. It is suggested that students' answers in these types of assessments may be biased toward intuitively appealing choices. If this is the case, one could expect students to improve their performance by engaging in more analytical reasoning. Research has shown that analytical reasoning is activated when people experience metacognitive difficulty or conflict. This paper outlines the results of an intervention designed to trigger one of such experiences by asking students to make predictions about the wrong answers most commonly selected by other students. Major findings show that this simple prompt had a significant positive impact on students' answers, regardless of their academic performance in the course.

Tan, C. (2017). Working with Concept-Based Curricula for Mathematics. In Tan, L. (Ed.) *Curriculum for High Ability Learners* (189-203). Singapore: Springer Nature
The purpose of this chapter was to address some of the challenges of delivering a concept-based curriculum in a typical mathematics classroom in a secondary school in Singapore, as well as documenting some of the teaching strategies that educators could use to promote conceptual understanding in students.

Tan, L. & Tan, L. (2017) Theory, Research and Conceptions of Curriculum for High Ability Learners: Key Findings, Issues and Debates. In Tan, L. (Ed.) *Curriculum for High Ability Learners* (11-24). Singapore: Springer Nature
This is the first chapter in a very important book on the issues of CBTL. It highlights key findings, issues and debates in the field of curriculum and instruction for high ability learners, specifically in four key areas. Firstly, the chapter explains the relations among the key elements that dictate curriculum development: (1) the intellectual characteristics of the learners; (2) curriculum principles, theories and models; and (3) the intended student outcomes. Secondly, it explores the idea that concepts are fundamental to learning, how and why teaching for conceptual understanding results in deeper learning and how teaching for conceptual understanding is different from teaching concepts. Thirdly, it examines the complexities of understanding what a concept is across different disciplines and then focuses on the tensions and challenges involved in designing and implementing concept-based curriculum.

Tan, S., Erdimez, O. & Zimmerman, R. (2017). Concept Mapping as a Tool to Develop and Measure Students' Understanding in Science. *Acta Didactica Napocensia*, 10 (2), 109-122
Concept maps measure a student's understanding of the complexity of concepts, and the interrelationships between sub-elements. Novak and Gowin (1984) claimed that the continuous use of concept maps increased the complexity and interconnectedness of students' understanding of relationships between concepts in a particular science domain. The study reported here had two purposes; firstly, to test this claim and examine how the repeated use of concept maps affected the complexity and interconnectedness of concepts in science subjects in elementary school, and secondly to compare a number of grading systems for concept maps. The sample group consisted of 23 students including 14 male and 9 female students. It was concluded that concept maps have the potential to measure change in complexity and interconnectivity of concept maps. Furthermore, repeated use of concept maps has the potential to increase the complexity and interconnectedness of student concept maps, and therefore improve their understanding of science content.

VanTassel-Baska, J. & Wood, S. (2010) The Integrated Curriculum Model (ICM). *Learning and Individual Differences* 20, 345–357
This article explores the Integrated Curriculum Model (ICM) which has been used worldwide to design differentiated curriculum, teaching, and assessment units of study for gifted learners. The article includes a literature review of appropriate curriculum features for the gifted, other curriculum models, the theoretical basis for the ICM model, a description of the model, research that has been conducted to date on its effectiveness, and specific implications for use in classroom settings in schools.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, 4(1), 45–70
This paper presents a theoretical framework that attempts to capture and model the kind of conceptual change that takes place in the process of acquiring knowledge about the physical world. It is suggested that individuals construct a naive set of theories about the physical world early in infancy. Such theories facilitate, but also constrain, the knowledge acquisition process. Information consistent with existing conceptual structures can be easily incorporated into the conceptual system. Information inconsistent with existing presuppositions and beliefs is difficult to understand and likely to give rise to misconceptions.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology*, 24, 535–585
This paper presents the results of an experiment which investigated elementary school children's conceptual knowledge about the earth. First, 3rd, and 5th grade children were

asked a series of questions about the shape of the earth. Children's responses to these questions revealed considerable inconsistency. For example, many children said that the earth was round but also stated that it has an end or edge from which people could fall. A great deal of this apparent inconsistency could be explained by assuming that the children used, in a consistent fashion, a mental model of the earth other than the spherical earth model. Five alternative mental models of the earth were identified: the rectangular earth, the disc earth, the dual earth, the hollow sphere, and the flattened sphere. It is argued that these models are constrained by certain presuppositions which children form based on interpretations of their everyday experience. Some of these models (the rectangular earth and the disc earth) seem to be initial models that children construct before they are exposed to the culturally accepted information that the earth is a sphere. In the process of knowledge acquisition, children appear to modify their initial models to make them more consistent with the culturally accepted model by gradually reinterpreting their presuppositions. Synthetic models (such as the hollow sphere and the flattened sphere) are generated by children as a solution to the problems arising from the inconsistency between their initial model of a flat earth and the culturally accepted, scientific model of a spherical earth. Children come to understand that the earth is a sphere only when the presuppositions that gave rise to their initial models have been reinterpreted.

Wiggins. G. & McTighe, J. (2005). *Understanding by Design* (2nd edition). Alexandria, VA.: Association for Supervision and Curriculum Development
Wiggins and McTighe present not only a framework to work on curriculum design in a more comprehensive, overarching, and thorough way but also a pedagogical as well as educational perspective that encourages teachers, students, leaders and even policy makers to reconsider the purpose, objectives, and impact that a thoughtful curriculum design can have for the school system in which it is implemented. In this book, the authors provide a clear depiction of both the theoretical foundations and the practical elements required for the construction of designs for learning, based around their three-staged backward design idea.

Wiliam, D. Lee, C., Harrison, C. & Black, P. (2004) Teachers developing assessment for learning: Impact on student achievement. *Assessment in Education* 11(1): 49-65
While it is generally acknowledged that increased use of formative assessment (or assessment for learning) leads to higher quality learning, it is often claimed that the pressure in schools to improve the results achieved by students in externally-set tests and examinations precludes its use. This paper reports on the achievement of secondary school students who worked in classrooms where teachers made time to develop formative assessment strategies. A total of 24 teachers (2 science and 2 mathematics teachers, in each of six schools in two LAs) were supported over a six-month period in exploring and planning their approach to formative assessment, and then the teachers put these plans into action with selected classes. The mean effect size of student achievement was 0.32, only moderate in terms of significance.

Williams, G. & Clement, J. (2015). Identifying Multiple Levels of Discussion-Based Teaching Strategies for Constructing Scientific Models. *International Journal of Science Education*, 37(1), 82-107
This study aimed to identify specific types of discussion-based strategies used by two successful high school physics teachers in teaching. Outcomes suggested that, in addition to previously documented dialogic strategies used by teachers in science classes, there is a second level of strategies that these teachers used in attempting to foster students' learning, and these were more focused on supporting student construction of cognitive models. The study attempts to contribute to a clearer understanding of how discussion-leading strategies may be used to scaffold the development of conceptual understanding.

Wray, D. & Lewis, M. (1997) *Extending Literacy*. London: RoutledgeFalmer
One of the most problematic areas in the teaching and development of literacy appears to concern children's interactions with non-fiction books. Many surveys and reports have commented on the tendency for children to do little more than copy out sections of non-fiction texts. The Exeter Extending Literacy (EXEL) project was set up with the aim of exploring ways in which non-fiction might be used more effectively and profitably than this. In this book David Wray and Maureen Lewis outline the thinking behind the project and describe in detail the many useful teaching strategies and approaches which were developed in collaboration with primary teachers across the country.

Yak-Foo, S. & Koh, K. (2017). Processes and Issues in Concept-Based Curriculum for the Humanities. In Tan, L. (Ed.) *Curriculum for High Ability Learners* (169-187). Singapore: Springer Nature
Humanities programmes offered by schools typically include subjects like geography, history, music and art. The focus of this chapter, however, is on how a concept-based curriculum unit in geography can be carried out and what the essential elements of such a unit are. The chapter shows how the design of such a unit can ensure ample opportunities for high ability learners to strengthen their intellectual capacities. The implications of implementing such a unit are also highlighted, and these include the likely challenges to be encountered and the suggestions that can help to manage them.