CONCEPT-BASED TEACHING AND LEARNING: A REVIEW OF THE RESEARCH LITERATURE

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Published as: Medwell, J. & Wray, D. (2020) "Concept-based teaching and learning: a review of the research literature". In Gómez Chova, L., López Martínez, A. & Candel Torres, I. (Eds) *Proceedings of the 13th International Conference of Education, Research and Innovation* (ICERI2020), ISBN: 978-84-09-24232-0, Valencia: IATED Academy, pp. 486-496

Abstract

In her seminal work on concept-based teaching and learning (CBTL), Hilda Taba emphasized the need for teaching to focus more on conceptual understandings rather than merely on teaching facts. CBTL aims to promote the learning of concepts, which supports the generation and understanding of ideas, the transfer of knowledge and skills, and a critical or reflective perspective towards knowledge itself. The aim of the study reported here was to critically review the research literature to identify the nature of CBTL and effective approaches to it. The review explored the nature of concepts and the development of conceptual understanding, leading on to the key features of a concept-based teaching approach.

Keywords: Concept-based teaching, concept learning, concept development.

1 INTRODUCTION

1.1 Why concept-based teaching and learning?

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 [1]. Taba's [2] claim was that, in order for teachers to teach effectively, they needed to understand levels of knowledge: from facts to underpinning concepts and principles. 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 [1].

Of course, the emphasis in schools on the teaching of facts has not 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 often seen as more important than the way the human brain actually works. Which does not mean to say that facts are redundant. Such a proposition has been strongly countered by commentators [3] [4] who argue that a knowledge base is crucial to being 'educated' and that new knowledge depends for its understanding upon a network of previously acquired knowledge. Yet it may be that facts are less useful today, in a world where we can always use Google to find things out [5]. How can schools ensure that what their students learn is not redundant by the time they emerge from compulsory education?

1.2 From facts to concepts

All knowledge exists at different levels of complexity [6]. 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, or '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. 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 experiences and seemingly isolated facts [7]. 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 [8].

It seems logical to suggest that concepts and facts require different approaches to teaching [1]. Teaching may proceed via direct instruction, or via inquiry-led approaches. Researchers [9] have suggested that direct instruction is a superior approach in terms of student learning outcomes, although this conclusion is not universally accepted. It has been argued, for example, [10] 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, 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.

1.3 Research questions

The aim of this study was to undertake a literature review to identify effective approaches to CBTL. Research questions for this study 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. What models of CBTL have been proposed and how do these align with typical concept development?
3. What teaching approaches and strategies appear to facilitate the development of conceptual understanding?

2 METHODOLOGY

Secondary studies, such as this, 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 [11]. In order to accomplish this, we first needed to locate such research papers, and a crucial step was to develop a search string which could be applied to existing databases of published research papers. Our initial search terms consisted of the following: "concepts", "concept development", "concept-based teaching", "concept-based learning", all combined using the Boolean term OR. 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.

The application of these filters had the effect of narrowing the hits to 1821 papers We then went through the entire list of hits, examining titles and abstracts and deleting those papers that did not meet our criteria of usefulness. 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 produced, inevitably, many duplicates but 5 hits were new to our process.

The selected papers were then categorised in terms of the main theme they addressed, defined according to our research questions. Each paper was skim read, paying particular attention to its abstract and conclusion, and then assigned to whichever research question it best fitted (and sometimes to more than one).

We were, at this point, ready for a detailed reading of the papers in our collection. It was at this point also that any necessary 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). The final review, reported below, was based upon a reading of 158 papers/books.

3 RESULTS

3.1 Research question 1: What are concepts and how do they typically develop in learners?

Within the context of human knowledge, knowledge representation has been defined [12] as “a systematic way of codifying human knowledge". A central part of such representation consists of elaborating: (a) a set of concepts about the world; and (b) the relationships between these [13]. 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 [14].

Concepts are mental representations of categories of objects, events, or other entities [15]. 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 and 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 [15].

The concepts referred to here are generally referred to as spontaneous concepts [16] and children naturally construct these in reference to the objects they encounter in their everyday lives and their perceptions of these objects [17]. 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 [16]. Organised teaching, designed to fulfil specific purposes, arouses children’s conscious awareness of a concept [18]. They are then given opportunities to practice and extend what they have learnt until they are in control of the concept at issue. The key factor is that scientific concepts are generalizable across situations, while spontaneous concepts are ways of categorising particular experiences.

It seems, then, that from an early age, humans build theories to explain their world [15]. Through experience, reflection and deliberate teaching, humans add and develop concepts as they learn. The cognitive process of adapting and restructuring these theories is conceptual change [19], a model which 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 existing mental models [20].

Piaget's [21] theory of cognitive development is perhaps the best known of all such theories. It emerged from extensive observation of children, including his own, in their natural environments rather than in laboratories and 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. Four key themes have emerged from research into concept development in young children [22].

- 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, and making inferences that extend knowledge beyond what is already known.
- Theme 2. Even pre-school children are capable of reasoning about abstract concepts. 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 [23].

- Theme 3. Children's concepts are not uniform across subject areas, across individuals, or across tasks. Specialist knowledge can exert surprisingly powerful effects, and experts do not seem to be more generally intelligent or skilled than novices but have superior knowledge which is localized within their domain of expertise [24] (Chi, 1978).
- 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, yet they may still inform their more general thinking. [25].

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 instances of it [26], [27]. Because concepts are highly contextual, choosing which concepts are appropriate for a particular age group of learners requires a value judgment on the part of teachers [28]. The notion of a "concept" encompasses a wide range of possible choices, varying in terms of their level of abstraction and/or universality [29]. One distinction has been made [30] 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. It has been argued [31] 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 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 trying to cover a great deal of material in a superficial way.

It also seems to be the case that students learn best when concepts are taught in the context of a specific domain of knowledge rather than in contexts that are more general [32], and 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 [14].

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

From the above, it seems to make good sense to teach conceptually – which, however, begs the question of what constitutes conceptual teaching. Erickson [33] 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.

In a traditional classroom where the norm will tend to involve direct instruction, teaching often involves covering the subject content prescribed in a textbook in a sequential manner. Such an approach means that all the content has to be covered, and this knowledge is taught discretely with limited connections to the rest of the curriculum or previous knowledge and 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 their wider lives.

There is not, of course, only one model of how such teaching and learning should be implemented. A range of alternative models of concept-focused teaching and learning will be examined and discussed.

<u>1. Applebee curriculum integration model</u>

Applebee's [34] 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 lists of items, information, and events, but rather, be organised to enable students to participate in an extended conversation, with language episodes of high quality and an appropriate breadth.

2. The 5E Teaching Model

Reports on the use of concept-based teaching have begun to appear in the educational research literature, relating to a wide range of curriculum subjects and age phases. For example, in some work with young children on Astronomy [35] in order to avoid the mistake of watering down content, a concept-based approach was used, involving the use of modelling, demonstration, explanation and questioning, set within the 5E teaching model [36], using 5 phases of activity: Engagement, Exploration, Explanation, Elaboration and Evaluation. Although no details are given of any assessments made of children's learning progress following this teaching, it is noteworthy for its deliberate focus on younger children.

3. The STS Approach

A teaching model which has been evaluated quantitatively is that proposed by the National Science Teachers Association [37]. The aims of this Science-Technology-Science (STS) approach to teaching science are to develop decision-making and problem-solving skills in order to help students understand socio-scientific issues [38]. Its benefits lie in its involving students in trying to solve problems that are relevant to their daily lives and seeking out information to use for this purpose. In one study of 609 twelve to sixteen year olds [39], students who experienced the STS approach in their science classes 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.

4. The Graphic Organiser Model

This model [40] 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 their use of it across a range of instances.

A key feature of this model is the use of the innovative assessment tool of the open-ended essay. It has been reported [40] 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.

5. The Integrated Curriculum Model

The Integrated Curriculum Model [41] was developed for use with gifted learners and is focused around three dimensions:

1. Emphasizing advanced conceptual knowledge in disciplines.
2. Providing higher-order thinking and processing.
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 not simply because it is deliberately aimed at gifted learners, but it has also received extensive research evaluation [41] in which enhanced student learning has been demonstrated many times.

6. Understanding By Design

Another popular curriculum planning model which foregrounds concept-based teaching is Understanding by Design (UbD) [42]. This model has a number of distinctive features, perhaps the most influential of which has been the notion of "Backward Design", in which teaching 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.

The primary goal of UbD is student understanding: the ability to make meaning of "big ideas" and transfer their learning. This is demonstrated when students autonomously transfer their learning to authentic performance. Teachers are viewed as coaches of understanding, not mere transmitters of content. Although the developers [42] 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. A paper is available [43] reviewing the research evidence underpinning the model.

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 [44]. 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).

There have been some empirical studies of Erickson's approach in action including a case study [45] 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. This focus upon the teachers who have to implement an innovative curriculum also appeared in another study [46] targeting secondary teachers implementing concept-based instruction in a number of US schools. The key issue emerging was that success in implementing CBTL depended crucially on the degree to which a teacher was trained and prepared for such a task. 5 of the 8 teachers in this study had actually abandoned a CBTL approach by the end of the research, due to lack of school support.

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

According to Erickson [33], [27], concept-based teaching 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 [47]. These big ideas take the form of concepts and generalisations which 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.

The CBTL process has been characterised as a learning cycle and involves teachers structuring their lessons to ensure inquiry-based instruction is included [48]. This cycle is based upon constructivist-teaching methods, in which inquiry-based strategies are emphasized, to allow students to explore and develop concepts [49]. One example of such a cycle is the 5E teaching model [36] reviewed earlier and research into the effectiveness of the learning cycle [50] suggests it to be particularly successful in the teaching of sciences.

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, the IRF pattern [51], is perhaps one of the mostly widely found features of classrooms. The implications of

such a dominant pattern of discourse 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 [44].

This does not imply that teachers should not ask questions in lessons. It has been suggested [52], 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 - 'what' questions; conceptual questions, which connect this factual content with the concepts which underpin it – 'how' or 'why' questions; open questions, sometimes called debatable or provocative questions, which provoke thought and discussion.

Questioning in classrooms is a traditionally powerful activity and it has been suggested [53] 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 in that better hypotheses are found by steadily identifying and eliminating those that lead to contradictions [54]. Leading good discussions in the classroom is sometimes considered to be an art rather than a science, and the specific strategies that a teacher may employ to enable such conversations are not well understood. One categorisation of questioning strategies is OGEM [55].

- **O**bservations. E.g. Tell us what you saw when …
- **G**eneration. E.g. What explanation can you give for …
- **E**valuation. E.g. Do you agree with …
- **M**odification. E.g. Does anyone see it differently?

This categorisation is very reminiscent of the model of dialogic teaching put forward by Alexander [56], and extensively investigated in primary classrooms, with the most recent study [56 finding that pupils experiencing a dialogic teaching intervention had made on average two months more progress in their learning than a comparable control group.

In a more general sense, active-learning pedagogies have been shown to improve student conceptual understanding [57]. 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 [58]. A research review [59] found that there was broad support for the core elements of active, collaborative, cooperative and problem-based learning. Active, or action, learning also links very strongly with Problem-Based Learning (PBL).

Concept mapping is also a tool that has been demonstrated repeatedly to have a positive impact on the quality of student learning [60], [61]. Concept maps appear to allow students to link new knowledge with existing knowledge and promote a problem-solving approach to student thinking and have been widely used in various courses at a range of levels [62].

4 CONCLUSIONS

A detailed review of research material was carried out for this study, during the course of which 158 papers were read and evaluated. This literature review was organised around three main headings.

1. 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.
2. A number of models of CBTL have been described, although not all of these have been subjected to rigorous research evaluation.
3. Particular features of pedagogy are associated with CBTL in the literature, including inquiry-led learning, authentic learning activities, dialogic discussion and the use of concept mapping.

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