FEATURE ARTICLE

A Journey from Content to Concept Teaching in a Biology Classroom, in the Context of Blended Learning

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Abstract

Conceptual teaching was developed three decades ago as an alternative to conventional teaching approaches. It promised a significant shift in teaching practices across different disciplines and age groups. Traditionally, science subjects in high school tend to be content-heavy. Teaching science, especially biology, is still rooted in teaching methods that facilitate factual understanding and low-road transfer of knowledge. As a result, students' knowledge remains compartmentalized. Students rarely make connections with other disciplines and transfer their biological knowledge to new situations. Bringing concepts to biology is a challenging task. Despite compelling evidence for concept-based teaching, there are few examples of how it can be implemented and replace content-based teaching. This article describes the changes to teaching instructions in biology over the last decade as well as the main challenges that prevent incorporating novel teaching approaches in a biology classroom. The author suggests concept-based teaching as an effective alternative to conventional, content-focused teaching and offers some ideas for implementing concepts into teaching biology in the context of blended learning.

Key Words: *biology; blended learning; concepts; conceptual teaching, content-based teaching*

"This could be the beginning of a long-awaited revolution in teaching biology that will prepare future generations of creative innovators and problem solvers."

For many years, biology curricula were designed to transfer mainly factual knowledge (Linn et al., 2016). They failed to emphasize concepts, instead encouraging cognitively shallow teaching and learning (Erickson & Tomlinson, 2007). Simultaneously, biology content grew exponentially, resulting in textbooks that contained more information than students could process (Dolan, 2010; Çimer, 2012; Hadiprayitno, 2019). In 1983, two-time Nobel Prize winner Linus Pauling brought this content overload to the world's attention, stating: "I think we shall have much more success in teaching science when the textbooks contain 200,000 or 300,000 words instead of 500,000 or 600,000. We must ask ourselves: Are students today more brilliant than they were in the past?" (p. 25).

This trend forced many students to simply memorize facts, to the detriment of their conceptual understanding (Gabel, 2003; Daniel, 2016). Smith and Colby (2007) described this approach as reproduction, categorizing of information, or replication of a simple procedure. In this approach, learners accept information and ideas, memorize facts, and concentrate on assessment requirements. It echoes behaviorism in that it considers learning to be a pure stimulus-reaction mechanism based on conditioning (Motschnig-Pitrik & Holzinger, 2002). Perkins and Salomon (1992) called this a "low-road transfer of knowledge," one that involves tasks that trigger well-practiced routines by stimulus conditions similar to those in the learning context (p. 8). Teachers delivering only this content tend to lecture students and to promote intellectual passivity and poor retention of factual knowledge (Stover, 2016). Many attempts have been made to emphasize the need to change teaching styles, including how we teach biology in secondary schools. One of the first voices advocating a change was Dewey (1916):

> To learn from experience is to make a backward and forward connection between what we do to things and what we enjoy or suffer from things in consequence. Under such conditions, doing becomes trying; an experiment with the world to find out what it is like; the undergoing becomes instruction. (p. 44)

In his book *Democracy and Education*, Dewey (1916) emphasized the importance of learning by doing, which other researchers in education built on. The work of Piaget (1952) on the growth of the intellectual functioning of children shed new light on teaching science. His concept of the construction of mental structures as the fundamental process in intellectual development impacted teaching instruction and the view of the learning cycle (Lawson & Renner, 1975). The instructional techniques inspired by the Piagetian theory were incorporated into the science curriculum. The learning cycle in science was revisited and based on the three-phase process of exploration, invention, and discovery (Atkin & Karplus, 1962). Exploration means

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acquiring knowledge through experience with physical materials. At the invention stage, students order their experiences and form mental structures. Students in the discovery phase further explore their experiences, develop understanding, and conceptualize factual knowledge. This learning cycle fosters conceptual understanding and helps learners move from acquiring factual knowledge to developing abstract mental conceptualizations (Lawson & Renner, 1975). Beyond Piaget's understanding of conceptual development, researchers such as Donaldson (1986) determined that children are capable of abstract thinking and operating with concepts. In another study, Chadwick (2009) suggested that the development of conceptual understanding appears to be cumulative. As learners revisit existing concepts in various contexts as they learn, they gradually increase the breadth, depth, and complexity of their understanding. Over time, learners can not only identify concepts but also use them in different contexts; they make multiple connections between concepts; and they are able to apply and transfer concepts to more complex and remote contexts (Medwell et al., 2019).

In the past two decades, researchers have sought to refine what should be taught in science in secondary schools and how it should be delivered. They developed a set of measures that define "scientific literacy" or "science literacy" (Bybee et al., 2009). The current trend is to emphasize constructing an understanding of scientific phenomena rather than merely acquiring factual knowledge. A large body of literature reports investigations of teaching approaches that foster critical thinking and conceptual understanding in science, such as team-based learning (Carmichael, 2009), problem-based learning (Yadav et al., 2011), and process-oriented, inquiry-based learning (Koballa, 1986; Krajcik et al., 2000; Brown, 2010). Accordingly, science teachers are viewed as scaffolders and facilitators of students' conceptual understanding. They support students' participation in scientific discourse and inquiry-focused activities (Windschitl et al., 2012) in which students are active constructors of conceptual understanding rather than passive receivers of factual knowledge.

Concept-based teaching originated in the works of Hilda Taba in the early 1960s. In her book ***Curriculum Development: Theory and Practice***, Taba (1962) argued that effective teaching is based on the understanding of three levels of knowledge: facts, basic ideas, and principles. She emphasized the need to focus on developing conceptual understanding rather than merely delivering factual knowledge (Medwell et al., 2019). Her observations revealed that if students were overloaded with information, they found it difficult to make connections between the new information and their existing information or prior knowledge (Taba, 1962). She suggested that effective learning can happen when students are encouraged to make generalizations. From further work, Taba et al. (1971) explained that generalizations, such as concepts, are the end products of a process of an individual's abstracting from a group of items, and concepts are the building blocks for generalizations. A concept is directly related to a schema that forms a mental framework for understanding. Other researchers who developed concept-based instruction models echoed this view (Erickson, 2002; Avery & Little, 2003; Wiggins & McTighe, 2005; VanTassel-Baska & Wood, 2010). Currently, concepts are defined as mental representations of categories of objects, events, or other entities (Jonasson, 2006). They are, thus, abstractions learners make and are interchangeably called ***big ideas***, as Taba (1962) originally proposed. Gütl and Garcia-Barrios (2005) pointed out that learners tend to simplify, unify, and cluster facts by forming concepts as well as interrelating them to build a knowledge structure for their thoughts and notions. Concepts are generally defined as tools for organizing learning experiences as well as making them transferable and universal across different disciplines. While a variety of definitions of ***concept*** have been suggested, this article will use Erickson and Lanning's (2013) definition: a mental construct that is timeless, universal, and abstract to different degrees (p. 33).

Concepts in science are characterized by a high level of abstraction in verbal clues and labels, such as interdependence, unity, diversity, and continuity. They are also highly contextual and subject to change over time (Milligan & Wood, 2010). Researchers have attempted to categorize scientific concepts by their level of abstraction (Little, 2017). However, definitions and interpretations of the scientific concepts significantly differ and thus become challenging for teachers to understand and implement into learning experiences (Sunder, 2016). Milligan and Wood (2010) brought up another issue: appropriateness of concepts depending on the learner's age and cognitive abilities. Piaget (1952) suggested that students aged 6 to 12 tend to operate within the concrete operational stage that allows them to understand the basic concepts, such as volume, mass, or light. They also are able to build conceptual understanding using their past experiences and logical manipulation of symbols related to concrete objects. On the other hand, adolescents aged 12 to 18 gradually move into the formal operational stage that allows them to understand abstractions and apply concepts to various contexts.

The most significant change that occurs in this age group is the ability to transfer concepts into different disciplines. Whereas younger learners can define and describe scientific concepts, adolescents are able to transfer concepts introduced, for example, in chemistry and use them in biology to solve a novel scientific problem. In addition, they can formulate hypotheses, make analogies, and effectively comprehend abstract ideas from distant contexts. Most importantly, adolescents' thinking becomes multidimensional and relative rather than absolute. In other words, they see and can analyze scientific phenomena through multiple lenses and perspectives. Finally, teenagers are more likely to question others' ideas and less likely to accept facts as absolute truths (Medwell et al., 2019).

The above description of learners' cognitive development raises a challenge for teachers. They must continually consider students' abilities in unpacking. In an average classroom, students are at different levels of cognitive development even if they are at a similar age. Thus, Chadwick (2009) urged all educators to be ready to detect changes in learners' conceptual understanding by looking at students' abilities to

- understand and use abstract concepts,
- make connections between multiple concepts,
- formulate different interpretations of concepts, and
- apply and transfer concepts.

This implies that teachers are well trained and fully capable of diagnosing the conceptual understanding of learners. However, concept-based teaching is a relatively new approach that may be challenging for many educators to adopt, especially in secondary science classrooms.

In particular, biology teachers tend to focus on breaking down and explaining an ever-increasing amount of content. They are comfortable with the content-based teaching that was passed between generations of teachers over the last century (Stover, 2016). Their perspectives about teaching biology may be rooted in their learning experiences and interactions in classrooms where lecturing and passive transfer of knowledge were common. Numerous studies have reported that positive attitudes shaped in teachers by their learning experiences impact their confidence in the subject content, their willingness to utilize pedagogical innovations, and their commitment to student learning (Barros & Elia, 1998; Munck, 2007). In a conventional biology classroom, teaching is often topic based and frequently involves covering the subject content prescribed in a textbook sequentially. Many teachers may be under the impression that all the content is equally important and must be covered. The end goal for students is factual knowledge acquisition. Teachers present and explain facts, but they rarely encourage students to make connections and transfer learning to other areas of biology or to other disciplines. This trend is especially visible in secondary schools (Tröbst et al., 2016). It has been suggested that secondary education introduces the compartmentalization of science and subject-specific teaching instructions that are less student centered (Shrigley, 1983; Prenzel et al., 2012).

In the same vein, Michael (2007) pointed out that science teachers reluctantly incorporate new teaching approaches due to time constraints and concerns regarding the efficacy of practice. The common prevalence of passive, teacher-focused learning of science has become an issue in many countries and curricula (Daniel, 2016). Supporting this view, Leo and Puzio (2016) claim that secondary biology is taught through lecture and note taking that can be considered low-engagement teaching. Interestingly, Munck (2007) concluded that teachers assume that they use inquiry- and concept-based teaching practices. However, her findings suggested that teachers view teacher-directed activities or teacher-performed demonstrations as being inquiry and concept based. Multiple classroom observations revealed the disconnect between the teachers' understanding of these approaches and the accepted definitions. The results of Munck's (2007) study suggest that teachers have little understanding of conceptual teaching and lack the ability to use concepts to explain biological phenomena. Undoubtedly, more research is needed to fully assess teachers' perception, understanding, and execution of concept-based teaching in secondary biology classrooms.

A growing body of literature suggests that concepts help learners process and make sense of the large amount of information they encounter in science subjects as well as retain understanding and transfer knowledge to other contexts (Edmondson, 2005; Gütl & Garcia-Barrios, 2005; Birbili, 2015; Hwang, 2016; Little, 2017). In their seminal article, Kapici et al. (2017) argued that it is important for students to learn concepts and use them for solving problems and further learning. Much of the current literature on teaching instructions and curriculum development suggests a need for a shift in teaching, to make it more about helping students find and make sense of factual knowledge and less about delivering it to them (Erickson et al., 2017; Little, 2017). Concept-based teaching allows for reshaping and directing the learning experience toward meaning making and the learners' ability to categorize, integrate, and transfer understanding in multiple contexts. Taba (1962) suggested that curriculum content coverage could be changed by allowing the concepts, the generalizations, to determine the direction and depth of the teaching. In reviewing Bloom's taxonomy, Krathwohl (2002) argued that conceptual knowledge plays a critical role in moving students from knowledge to understanding. The concepts serve as building blocks for schemas and frameworks and provide a basis for understanding. He urged educators to teach toward a deep understanding of conceptual knowledge, not just toward remembering factual knowledge. Concept-based teaching is conceived as a form of inductive teaching in which teachers guide learners to understand the big ideas rather than teaching directly about these ideas. The approach does not require teachers to present and explain the factual content of a subject. Instead, factual knowledge is reduced and reorganized to ensure that students can access the concepts in the form of generalizations.

What has been discussed so far suggests that there has been a paradigm shift in terms of models of successful teaching and learning. Teaching for conceptual understanding has been suggested as an effective approach within many curriculum frameworks, including the *Next Generation Science Standards*, in an age of rapid and constant change around what counts as scientific knowledge (Milligan & Wood, 2010). The new teaching reality has opened up previously unexplored ways of implementing conceptual teaching. In most schools around the globe, learning and teaching happen as a combination of on-site and online learning, allowing more flexible, efficient, and effective learning in the uncertain contexts of the COVID-19 pandemic (Stein & Graham, 2020). In blended learning, teachers often introduce content prior to a learning experience to build factual knowledge foundations (i.e., flipped classroom). Educational materials can be provided in a variety of technological media that facilitate retention of facts. Similarly, students can prepare for the upcoming lesson before the class and then engage in learning with a teacher and other learners either virtually or in a classroom setting. Apparently, these are ideal conditions for focusing students' attention on concepts and conceptual understanding while having online or on-site interactions.

Teachers can introduce and unpack concepts using students' preexisting knowledge, and build a narrative around a concept. In this approach, students acquire factual knowledge through researching and active engagement with the task, in addition to using the content that was presented prior to the learning experience. As mentioned before, factual knowledge is reorganized, and instead of breaking down each piece of information, students are encouraged to formulate big ideas from smaller pieces of factual knowledge. In this scenario, concepts do not replace the content. On the contrary, they help bring context and purpose to the biological content students are exploring. In conventional teaching of biology, factual knowledge is introduced, explained, and often assessed by teachers in a single learning experience. By contrast, concept-based teaching encourages students to tackle a concept using various tools, such as case studies, real-life problems, and project-based learning to redirect students' attention to acquiring understanding rather than just retaining facts. The most successful teaching tools to introduce conceptual teaching and reduce the amount of content also include

- visible thinking routines,
- testing and formulating hypotheses,
- designing experiments,
- collecting evidence to support scientific claims,
- analyzing secondary data,
- using simulations to demonstrate patterns and trends,
- facilitating connections with other disciplines, and
- formulating analogies.

In addition, graphical representations of concepts in the form of diagrams or pictures can serve as another tool that can be used, especially by inexperienced teachers, to visualize concepts. Nowadays, the internet offers a plethora of software for designing visual stimuli (e.g., Canva) and applications (e.g., Mindomo) that enhance development of teaching tools to help students explore biological concepts. Furthermore, students can create a lab journal (e.g., using Padlet) that helps them document and solidify thinking around concepts. The lab journal has been used successfully by students to reflect on their learning by comparing their current thinking to their initial thoughts about concepts (Borda et al., 2017). Overall, there are several best practices in implementing concept-based teaching in biology classrooms that can easily be adapted in blended or virtual learning, offering alternatives to conventional, content-based teaching. This could be the beginning of a long-awaited revolution in teaching biology that will prepare future generations of creative innovators and problem solvers.

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