Feature Article

Constructivism and Student Misconceptions
WHY EVERY TEACHER NEEDS TO KNOW ABOUT THEM

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Abstract
Research indicates that in light of what is now known about how learning occurs, much teacher instruction is wasted time since teachers are failing to take into account the pre-existing beliefs of their students. If new information does not fit with what students already know they may simply choose to reject it outright, leaving our classrooms having learnt nothing.

WHAT IS CONSTRUCTIVISM?
When students come into the science lesson, we as teachers hope and usually expect that they will develop new concepts and understandings in response to our teaching.

Many of us assume that new learning will occur—all we have to do is impart new information and if the student is paying attention or is motivated, they will learn what has been taught. In other words, we believe learning is the result of teaching.

Constructivist Learning Theory maintains that learning is not the result of teaching, rather it is the result of what students do with the new information they are presented with. In other words, students are active learners who construct their own knowledge; they are not passive recipients of new information, somewhat like a sponge. Many teachers see this learning theory as just a new way of presenting what we already know—"okay, doesn't that mean the same as above, that students will construct new knowledge as the result of our teaching, as long as they are motivated or paying attention?" The answer is NO. While being motivated and paying attention to our delivery is of course a factor in learning, there is something even more important to be considered—what students already know.

STUDENTS' KNOWLEDGE BANK
By the time children start school they already have a huge knowledge bank of their own explanations for the way the world is. These are ideas that help them make sense of the world in which they live. They have been picked up from all sorts of experiences, events, places, people in their lives and of course, from the ever-present media. A child brings all this with him/her to the classroom. Much of it is at odds with current scientific views. These are misconceptions or wrong beliefs, and it is these beliefs, more than any other factor, which determine whether students will learn the new information that we present to them.

Preexisting understandings are the foundation upon which new knowledge is constructed. New conceptions are only learnt and retained if they can be fitted or joined to already existing knowledge. If the foundation is wrong, new knowledge will not 'stick'. Just as in constructing a building, if the foundation is not sound or is flawed, then no matter how perfect the bricks or the bricklaying technician, the new brickwork will not last, even though it may stick temporarily. In other words no new knowledge, in the sense of real learning, has occurred. Real knowledge requires deep understanding. As Albert Einstein once said, "You do not really understand something unless you can explain it to your grandmother" or in the words of Giambatista Vico 1710, perhaps the first constructivist philosopher, "one only knows something if one can explain it."

DEALING WITH NEW INFORMATION – FOUR CHOICES
When students come into a learning situation where they are presented with new information that differs from their previous understandings or knowledge, they can deal with it in one of four different ways:
1. DELETE the preexisting knowledge
2. MODIFY the preexisting knowledge so that it fits the new information.
1. Deleting the existing wrong beliefs

This sounds easy, much like pressing the DELETE button on a computer. The reality is that this is the most difficult of all four options. What we know is part of who we are. We can’t just ‘unknow’ what we know. The older we are, the more difficult this is. Thomas, Cardinal Wolsey (1471-1530) said, “Be very, very careful what you put into that head, because you will never, ever get it out”. It is human nature not to want to change what we know. What we know meets our needs as we cope with the world. We will only alter or change what we know if it no longer meets our needs, if it becomes inadequate.

Children in science classes are no different. Most are quite content with what they know and believe and merely informing them that what they know is wrong or that the new knowledge is ‘in the test’ is not reason enough for them to delete what is already there. Some may appear to do so using the test as motivation, but what is actually happening is that the new knowledge is just sitting there with the old knowledge under it, a flawed foundation. It lasts until the test is over then it slides away, forgotten. It is a ‘mismatch’ with what is known, so it cannot ‘stick’.

This explains why many students can pass tests on different topics while in reality no real learning, based on understanding, has occurred. Many students have us fooled. They have worked out, through years of practice, the ‘strategies for passing tests’. They can predict the required definitions that will appear in the tests, they have mastered the algorithms of Mathematics and Chemistry as well as the techniques for employing them and can repeat things we have said verbatim. Even our best students can give the ‘right’ answers but they are only using correctly memorized words. However, if we ask the right questions in an attempt to discover depth of concept understanding we will often be disappointed at just how little they have understood.

Research has demonstrated the persistence of student misconceptions and the tendency for regression to these misconceptions after courses of instruction. Mestre, (1989) reports “students who overcome a misconception after ordinary instruction often return to it only a short time later”. This verifies the previous argument, that students can convince us that their previous knowledge has been altered when in fact it is only a temporary strategy designed to pass a test. Ordinary people on the street still have the wrong beliefs about the world and how it operates years after having ‘learnt’ differently in schools. For most people, what they were taught at school in Science about how the world operates is largely at odds with what they believe and understand – what they know. Preconceptions are tenacious; we hold onto them with great vigor unless forced to change.

Even when someone tells us we are wrong this is usually insufficient reason to change what we know. Even Science teacher demonstrations so we can ‘see with our own eyes’ may not be catalyst enough to press our DELETE button. For example, research has shown that even when confronted with visual evidence that in a vacuum stones and feathers fall at the same rate, students do not recognize that all objects fall at the same rate without air resistance. Instead, those students observing it as some sort of ‘science trick’ see the demonstration whose results must be known for the next test. So too, with our own teacher demonstrations. Research performed on misconceptions in science indicates that it is possible “children develop parallel but mutually inconsistent explanations of scientific concepts, one for use in school and one for use in the ‘real world’” (Trowbridge and Mintzes, 1985).

In a Science class (and indeed in classes of other disciplines) we as teachers are often asking students to delete a mental image that makes sense to them and maybe has for many, many years, so that they can replace it with facts which are not as intuitively acceptable. This is often an impossible task as to do so requires them to undo a mental framework of knowledge that they may have used for years in order to make sense of the world. It is perhaps no wonder that of the four options a student has to deal with new information that conflicts with existing knowledge, this is the one that is usually rejected.

2. Modifying the preexisting knowledge so that it ‘fits’ the new information

This option is almost as difficult as the first. It is, however, slightly easier since altering what we know does not require us to forego what we know. This is a lot more preferable than admitting we are ‘wrong’ which is what deleting what we know really means. Many of us can easily relate to this option as one which salvages pride.
None of us like to admit, even to ourselves, that we are wrong. Being able to keep what we know with maybe a few modifications ensures our ego remains intact. Most of us are prepared to make a few small changes to our existing knowledge so that it will fit new information. So too with our students. Many are prepared to make minor alterations to existing mental frameworks if this is all that it required for new information to 'fit'. However this is still far from the preferred option. This requires mental effort. Where students are concerned, and many adults, the mental effort required to alter preconceptions is 'too hard'. Remember that students will only change their beliefs if they no longer meet their needs. Most of them do not see much scientific knowledge as relevant to their daily lives. They can quite easily live with their wrong scientific beliefs. They have no need to change except maybe to pass a test, and we have previously seen that this can be done temporarily by many of them without actually altering what they believe.

3. Modifying the new information so that it 'fits' what is already known

This is often what happens in our classroom. In order to 'fit' the existing misconceptions the incoming information must be altered or distorted to such a degree that it is actually wrong. Another misconception has occurred. Where there was one, now there are two. However, this too requires mental effort on the part of the student. It requires work, which for many is 'too hard'. For this reason it is not the preferred option. Students are, sadly, reluctant thinkers. When given a choice they will more often than not choose not to think. They will instead move to the next and easiest option, unequivocal rejection of the new information.

4. Rejecting the new information

Unfortunately, this is the most preferred option of many students and their most common reaction to new information that conflicts with their existing beliefs. This requires no mental effort, no reconstruction of preexisting knowledge, and students emerge from the Science lesson quite content with what they have always known. When a parent or interested other teacher asks them 'what they learnt in Science today' the student often replies "not much", or if pushed by the enquirer struggles to remember something. This is often put down to reluctance to talk to adults, if the student is an adolescent, but the reality is that they did indeed fail to learn much, if anything at all. If they care about their test marks (maybe due to parental pressure) they will cram for a test the night before and usually pass, with very little real learning having occurred.

FEWER MISCONCEPTIONS – MORE LEARNING

The students who do learn as a result of our instruction are usually those who come to the lesson with no or few misconceptions. These are more than likely the minority, the half dozen bright students who might come from a home where parents are well educated, where wide reading is encouraged, where access to encyclopedias and other sources of scientific knowledge is available, where the family watches natural history and other scientific programs on television and so on. In short, often students who are most like ourselves. They often have similar learning styles to us. They learn relatively quickly. The new information connects onto their pre-existing knowledge with ease and students understand the concepts. For this handful of students, our style of teaching produces results. Unfortunately it is the success of this minority upon whom we gauge our success as teachers. For the majority however, the current delivery system has failed.

To maximize the likelihood of new
learning occurring in our classrooms it is vital that teachers take existing student knowledge into account. We have often treated student minds as 'blank slates' onto which we can unload concepts. If this were so, education would be simple. It is in fact re-education that is difficult — overcoming student misconceptions.

Many teachers, especially new ones, have no idea about possible student misconceptions relating to the topic they are teaching. If a teacher begins a lesson with the standard half a dozen questions as a 'lead in' to the lesson (as we are taught to do at teachers' college) they may discover students have some 'funny ideas'. We just dismiss them or laugh about them later with colleagues, as we focus on the content we are about to deliver. In the past we have underestimated the persistence of these barriers to true understanding; we have failed to realise how important these ideas are in the learning situation. Constructivism tells us that these should perhaps be the focus of our lesson. In the past we have wrongly assumed that when faced with a teacher telling them they are wrong about something students will naturally dismiss their wrong ideas and that our teaching skills will ensure that this is automatic. We now know this is not the case.

OVERCOMING STUDENT MISCONCEPTIONS

Firstly, and perhaps most importantly, don't add to them! When children first start school they have many wrong beliefs about their world which come from mummy and daddy, grandpa, television, comics - all sorts of places. Unfortunately, by the time they begin high school they have acquired many, many more. Elementary teachers have a large responsibility to themselves understand the concepts they teach children in their classes. Research indicates that teachers in primary schools are reluctant to teach Science, feeling inadequate and under trained. This may be true but the answer does not lie in not teaching Science at all. Rather, teachers should seek help from specialist teachers in high schools, something that many have been reluctant to do in the past. With relatively easy access to information teachers should not hesitate in suggesting that students themselves find out the answers to the questions they might have about a topic, rather than teachers who are unsure of the answers supplying them. Finally, in-service training is essential and something which education systems and governments cannot afford to overlook.

Not to single out primary teachers as possible sources of student misconceptions, teachers in middle schools who are expected and encouraged to teach subjects outside their areas of expertise are also in danger of contributing wrong beliefs - beliefs that may become barriers to learning not only throughout students' secondary schooling but also throughout tertiary education. Such teachers are often given very little training, if any. While themselves grappling with content which is unfamiliar to them they may unwittingly pass on their own misconceptions to students. It is difficult to focus on student understanding and higher order processes when circumstances may determine a focus on content. Addressing and dealing with student misconceptions in such a situation is virtually impossible.

TEXTBOOKS OFTEN TO BLAME

Though difficult to comprehend, science textbooks themselves are often riddled with misconceptions! Recent research undertaken in the United States (Shapiro, 1989), uncovered what was described as 'The Great Science Textbook Scandal'. Where such errors exist untrained teachers and indeed trained teachers who are in the habit of believing the content of all textbooks to be true, fail to recognize these errors and unwittingly pass them on to their students. In addition to these possible sources of wrong beliefs many specialist science teachers themselves are often guilty of adding to the problem in that we present course material in such a way as to result in students forming misconceptions as a result of what we omit to tell them. For example I have recently completed a study of one hundred and ninety students aged between thirteen and seventeen across three schools in Mandurah, Western Australia, which revealed that the great majority of students in years 9-11 believe that there is no connection or relationship between atoms and cells. Each, students write, belongs to a different field of scientific study, namely living and non-living things. Many are so confused as to believe that atoms are made up of three types of cells: protons, neutrons and electrons! (Sewell, 2002) Such misconceptions arise because we teach the subjects and their related concepts separately, usually for a term at a time, and often fail to mention how these areas of study connect.

FOREWARNED IS FOREARMED

Being aware of what the wrong beliefs are is the next step in attempting to overcome them. We must become good listeners. As we have seen, many student misconceptions are highly resistant to eradication. Research indicates that many will never be overcome. (Wandersee, J.H., Mintzes, J.J.
Teachers can only do the best they can. Knowing what the misconceptions are is being forearmed. Many research studies, mostly overseas, have identified common student misconceptions in a wide variety of areas, including Science. These are contained in numerous journals. If these are not easily accessible, simply ask students. I have found that this works best with younger students but is not as successful with adolescents. Students who are trying to discover their identity and are struggling with peer relationships and so on become vulnerable if they volunteer what they know to their peers. Asking them to write down what they know is more successful.

Then having read the responses, teachers can plan their lesson to address the misconceptions they know their students have. Finding out what the misconceptions are at the commencement of the lesson is not going to have a great affect on the lesson that has already been planned. Find out the misconceptions before you plan the lesson.

Misconceptions are often identified after the course of instruction when students are required to explain their reasoning on answers to test questions. Also, asking students to represent their understanding of a subject in a diagram or flow chart can be a useful means of uncovering their misconceptions.

**CONFLICT IS NEEDED**

Teachers best address misconceptions by presenting information which conflicts with the students’ wrong beliefs. Students are then forced to compare what they know with what has been presented to them and to either reconstruct their knowledge or reject the new information. As we have seen, they will only construct new knowledge where existing knowledge fails to meet their need to make sense of the world to enable them to cope more effectively in it. This means the new information must be presented in a way that is relevant. If it is not relevant, students do not need it. Confronting students with new information which is visual, that is, carefully selected demonstrations, may work. In addition, collaborative discourse or small group discussion with peers can have some success in overcoming misconceptions that are common to several students. In order to convince someone else that you are right and they are wrong requires a thorough understanding of the concepts being presented. Having a teacher act as facilitator or ‘Devil’s Advocate’ to maximize exposure to incorrect beliefs in such a group discussion is very important. In other words, teachers are providing a forum in which students can confront their wrong beliefs.

This Socratic approach to teaching actually parallels what goes on in Science. Scientists theorise about explanations for certain phenomena, testing and looking for consequences of their explanations and attempting to construct something that makes sense to them logically and fits all the available data. This is what teachers should be encouraging their students to do.

Several researchers (Novak, 1987) have found evidence that asking students to create ‘concept maps’ in which they are constructing a correct framework for new knowledge has been successful in overcoming wrong beliefs, particularly if it is done in cooperative groups.

Assisting students to overcome misconceptions can be a difficult and time consuming task, one which takes time away from other Science activities. It is this that often deters teachers from making the effort. They complain that they haven’t the time, there is too much content to cover. The answer is simple. If our lessons do not attempt to build on the students’ correct understanding of concepts then the other, ‘more important’ science activities may be a total waste of time anyway.

**References**


