Bakhtin

▶ Socio-Cultural Perspectives on Learning Science

Beliefs

William W. Cobern
The Mallinson Institute for Science Education,
Western Michigan University, Kalamazoo,
MI, USA

The concept of "belief" is frequently contrasted with the concept of "knowledge," where in everyday language "knowledge" is thought of as "reasoned belief" that a proposition is true. One can understand a concept, for example, evolution, while believing the concept either to be true or false. Belief is a personal, subjective affirmation or rejection of the truthfulness of the proposition. Hence, belief and knowledge do not stand in opposition but work in conjunction (Cobern 2000; Quinton 1967). Because these concepts work in conjunction, it is also inaccurate to refer to things that are believed as opposed to things that are known. When belief and knowledge are contrasted in this way, it is typical for belief to be thought of as "blind" belief, in other words believing something to be true without any evidence or reason. However, no one holds a belief for no reason; it is just that there are many varieties of reason. For example, one may believe a proposition of science to be true because of the experimental data provided by a scientist in support of that proposition. That being said, a person may not be informed well enough to understand the evidentiary base for the proposition, but the person trusts in the authority of science. In this case, what is believed to be true is not blind belief but belief based on authority. Controversy arises however because not all authorities are equally trusted by all persons. Therefore in any discussion of belief, it is always important to understand the reasoning that is used in support of the belief (Stenmark 1995). Similarly, it should not be assumed that knowledge of something is the same as believing something to be true.

Cross-References

▶ Attitudes to Science and to Learning Science
▶ Attitudes Toward Science, Assessment of
▶ Cultural Change
▶ Curriculum and Values

References

Cobern WW (2000) The nature of science and the role of knowledge and belief. Sci & Educ 9(3):219–246

Quinton A (1967) Knowledge and belief. In: Edwards P (ed) The encyclopedia of philosophy New York. Macmillan Publishing Co, New York, pp 345–352

Stenmark M (1995) Rationality in science, religion, and everyday life. University of Notre Dame Press, Notre Dame

R. Gunstone (ed.), *Encyclopedia of Science Education*, DOI 10.1007/978-94-007-2150-0,

Bildung

Helmut Fischler
Freie Universität Berlin, Berlin, Germany

Introduction

The concept of *Bildung* is a major influence on discussions about, and reflections on, educational goals in the German-speaking countries and other Northern European countries with a similar cultural and linguistic background. *Bildung* in this regional and linguistic context is the central notion describing the process of personal development and the outcome of this development process. *Bildung* is more than education, and there is no English term that denotes the concept of *Bildung* accurately. Nonetheless, it may serve as a bridge between two educational traditions when an American educational researcher proposes the following explanation of the meaning of *Bildung*:

> *Bildung* is a noun meaning something like 'being educated, educatedness.' It also carries the connotations of the word *bilden*, 'to form, to shape'. *Bildung* is thus best translated as 'formation', implying both the forming of the personality into a unity as well as the product of this formation and the particular 'formedness' that is represented *by* the person. (Westbury 2000, p. 24)

This might function as a first orientation but it will be clear from the following text that the term "formation" runs the risk of being misinterpreted as a one-sided process.

Historical Roots

In 1784, the philosopher Immanuel Kant began an essay on the question "What is Enlightenment?" with the much-cited sentence: "Enlightenment is man's emergence from his self-imposed immaturity." Scholars of different disciplines adopted this idea and adapted it to their specific area of expertise. It became closely interwoven into the idea of Bildung.

Among these scholars the philosopher of language, anthropologist, neo-humanist, and Prussian politician Wilhelm von Humboldt reflected on consequences for the phase of human beings' growing up. According to von Humboldt's ideas, neither adolescents' alignment to the demands of society, where criteria like usefulness and efficacy play a dominant role, nor their growing up free from cultural influences in the sense of Rousseau should be the guideline for the process and the state of *Bildung*. Von Humboldt combined both aspects and advocated a balance between them, stating that "the true purpose of humans is their highest and most proportional cultivation of their strengths as a whole." An indispensable condition for this development is civil liberty and, connected with liberty, diversity of situations. These situations are defined by cultural and societal characteristics. In von Humboldt's world there is no individuation without cultivation. In his idea of *Bildung*, the individual and humanity are two facets that are strongly interrelated to each other.

In the 1790s, von Humboldt argued that the ultimate task of life is to endow the concept "humanity" with as rich a content as possible. He believed that this could only be done by associating with the world in the most comprehensive, lively and freest interplay possible. This statement is an early formulation of a characteristic feature of our modern time, i.e., the necessary and paradoxical concurrence of the processes of cultivation and individuation. Or as Immanuel Kant, the great apologist of the idea of liberty, put it shortly after von Humboldt:

> One of the most serious problems of education is how to combine the individual's subjection to the legal constraints with the ability to use his/her freedom . . . How can I cultivate liberty with this restraint? (Kant 1803, p. 711)

According to Nordenbo (2002), "*Bildung* seeks to bring the unique individuality into a harmonious relationship with general objectivity" (p. 350). For von Humboldt, the people of ancient Greece were classic examples of humans struggling for a harmonious relationship between the individual self and the world; therefore, he preferred the ancient languages Greek and

Roman as paradigmatic media offering appropriate access to *Bildung*. This preference was one of the reasons for the restriction of von Humboldt's ideas to the Prussian High School (Gymnasium) and for a lengthy debate about the suitability of different school subjects like mathematics or arts for achieving the goals of *Bildung*. Natural sciences were not regarded as a domain contributing to *Bildung* because of their usefulness in the century of industrialization. Members of society who were interested in the integration of the natural sciences into the school curriculum – pedagogues and politicians with a scientific background, representatives of industry and economy – emphasized the potential influences of these subjects on students' *Bildung* in the sense of Humboldt. In Germany, it took about a hundred years until the natural sciences were integrated into the school curriculum of the higher educational institutions (e.g., the Gymnasium), on an equal footing with the subjects already established. In the end, two kinds of pedagogical justification have been responsible for this integration: the traditional idea of *Bildung* (natural sciences are part of the efforts of humans to understand themselves in relation to the world around them) and the demands set by the society which expects the school to lay the foundation of expertise among as many members of society as possible, in order to meet the requirements of a technically oriented world. This twofold rationale nowadays constitutes the framework for all discussions and decisions concerning the structure of the curriculum in all school types.

A Modern Approach to *Bildung*

The different educational contexts within the historical development of the societies in which the concept of Bildung played a significant role led to various shifts in the meaning of *Bildung*. Wolfgang Klafki, the most prominent educational scientist seeking to develop for a modern understanding of *Bildung*, draws on ideas and descriptions presented in the decades around 1800 and points to their most significant features. For him, one of the most fundamental ideas that emerged at this time was the idea of the self-responsible, cosmopolitan person, contributing to his own destiny and capable of knowing, feeling, and acting. For Klafki (2000), the terms "self-determination, freedom, emancipation, autonomy, responsibility, reason, and independence" (p. 87) are crucial notions in relation to Bildung. But this is only one side of the overall meaning of *Bildung*. Klafki also stresses that this list of concepts could be misinterpreted as a description of *Bildung* as an individualistic conception; so he adds: "…the basic concept of subject- or self-determination is anything but subjective!" (p. 88). *Bildung* is also characterized by a second group of factors: humanity, humankind and humaneness, world, objectivity, and the general. *Bildung*, therefore, develops in the interplay between individual attributes, achievements, and expectations on the one hand and the conditions a person has to cope with on the other. These conditions are results of societal processes and comprise different kinds of social life as well as systems of norms and beliefs that pertain to the fields of politics, arts, science, and other domains. The interplay described mirrors a more differentiated process than Westbury's notion of "formation" can reflect.

In Klafki's view, the societal part of this interplay described has been not sufficiently analyzed by those who strive for a widely accepted conception of *Bildung*. He writes that "… the economic, social, and political conditions needed for the realization of this general demand for Bildung" (p. 89) were not examined consistently. In order to adjust the traditional conception of *Bildung* to the characteristics of individuals' contemporary environments, Klafki (1998) points to the direction in which the development of a modern version should be heading. At the core of these processes should be elaborated "a more differentiated and critical determination of the relationship between Bildung and society" (p. 313). Three abilities were, in this way, to be promoted by *Bildung*:

- Self-determination
- Codetermination (all people are invited to take part in the development of the society)
- Solidarity (with those whose opportunities for self-determination and codetermination are limited)

Bildung, as a process and its result, has to be permanently balanced between an adolescent's self-determination and his/her conformation to the demands of society. The German word "Erziehung" and the English word "education" are often used with the connotation "preparation for the demands of society." Therefore, "education" (like "Erziehung") covers only a part of the considerably broader spectrum of features that are characteristic for *Bildung*.

Variety

Because of the lack of a generally held understanding, there is a vast variety of contexts in which the notion of *Bildung* is part of the pedagogical and political discourse and of meanings that are linked to the term. Especially in public discussions, *Bildung* is reduced to become almost synonymous with "education." On the level of politics, the notion of *Bildung* has got such a general connotation that an interpretation is almost impossible. The German ministries that are responsible for the organization and structure of the educational systems (schools, kindergartens, vocational schools), and for the content-related issues within these systems, are ministries of *Bildung* although their political decisions mainly refer to the functioning of the state-run institutions. Because of this indistinct use of the term, the leading German theorist of *Bildung*, Tenorth, commented that *Bildung* can be regarded as a German myth, a pedagogical program, a political slogan, and an ideology of bourgeoisie. Often the term is used in connection with criticism of current society. In the light of this variety of meanings, does it make sense to use the term *Bildung* when any speaker or writer is likely to have a different conception in mind from that of the listener or reader? In Tenorth's view, *Bildung* still has great potential for describing the goals and processes of human growing up, especially if empirical aspects are integrated into the reflections on *Bildung* that have been shaped by mainly philosophical arguments.

Bildung and Scientific Literacy

In spite of the lack of a generally accepted understanding of *Bildung*, at least the core of the concept becomes clearer when it is compared or contrasted with the way the term "scientific literacy" has often been used in the last two decades. On the international level, in the OECD PISA project, scientific literacy focuses on the application of knowledge in science and so has a more functional connotation than *Bildung*. This interpretation of scientific literacy becomes visible in the statement of the OECD that the cognitive aspects of students' scientific literacy include students' knowledge and their capacity to use this knowledge effectively. The idea behind this statement is that education should prepare students for the demands imposed on them during their whole life. This idea becomes clearer in the OECD's more precise affirmation that the PISA tests cover scientific literacy, not so much in terms of mastery of the school curriculum, but in terms of important knowledge and skills needed in adult life. The conception of *Bildung* does not ignore the task of helping adolescents deal with the challenges of their future life. However, this educational aspect is embedded into a more holistic view, where universal principles like rationality, humanity, and morality are interwoven with an individual's growing up.

The dominant position of the term "scientific competency" in the description of the PISA program signals additional differences between *Bildung* and scientific literacy. As discussed above, the functional aspects of students' knowledge (competencies and skills) contrast with the concept and process of *Bildung*. So, for example, a phrase like "We teach children to be competent in a special domain," due to its one-sidedness, is not in line with the concept of *Bildung*. *Bildung* cannot be interpreted as the European version of scientific literacy, and in the process of selecting topics for the school curriculum, the question "Is it useful knowledge?" could be a guideline at best of secondary importance. An individual's knowledge and competencies represent only one facet of *Bildung*; another points to the individual's efforts to find his/her place in the rational, humane, scientific, and esthetic world. One of the most distinguished contemporary German pedagogues Hartmut von Hentig, well known as an author of fundamental reflections on *Bildung* and as a school and university teacher, has condensed these two facets into a depiction widely accepted: *Bildung* describes the tension or the bridge between ideals passed on and current needs of competence, between philosophical self-assurance and the practice-oriented self-preservation of society. In Plato's allegory of the cave, *Bildung* is both the rise towards sunlight and the descent towards the cave. The one without the other makes no sense.

Bildung Within Natural Sciences

Martin Wagenschein (2000) and other scholars have discussed how students' *Bildung* in natural sciences can be achieved. For Wagenschein, the main goal of science education is to help students understand phenomena of the natural world. To "understand" means to have gained insight into the essence of scientific relationships; it does not mean just to know the formula or to be able to apply it to a concrete problem. According to Wagenschein, there are three characteristic teaching-learning situations in which *Bildung* in this sense can develop:

- *Exemplary teaching*: In order to gain a deep understanding of a piece of content, it is necessary to invest a sufficient amount of time. Therefore, "we need the courage to leave gaps, in other words to be thorough and to deal intensively with selected examples" (Wagenschein 2000, p. 116). These examples have to be representative of the domain (its topics or methods) and at the same time exemplary as regards their contribution to students' *Bildung*.
- *Genetic teaching*: If the knowledge is to become an integral part of a student's Bildung, it is important that he/she has the opportunity to search productively for the solution of a problem, to find it, and to check it critically. From this perspective, Wagenschein, in the early 1950s, introduced elements of an idea that later, in its cognitive dimension, became known as the constructivist view of learning. Wagenschein emphasized the development of knowledge as much more than the result of the process of acquiring knowledge.
- *Socratic teaching*: A teaching-learning process which focuses on the development of knowledge is best arranged in a Socratic conversation. The teacher has to talk with his/her students not in a lecturing and dogmatic way but, like Socrates in his dialogues, focusing on their ideas and moderating their learning processes.

According to Wagenschein, teaching environments with this triad of principles are particularly suitable (and often necessary) for learning episodes in which a basic understanding of central notions and processes in natural sciences is to be acquired. This is the case especially in upper grades of elementary school and in lower grades of secondary school. However, Wagenschein's triad is meant to be effective at all levels, since the process of *Bildung* does not come to an end. Examples from physics and chemistry education (and a fuller discussion of several of the ideas discussed above) can be found in Fischler (2011).

Critics of Wagenschein's view of teaching and learning complain that it is too time-consuming and, because of its exemplary character, about students lacking knowledge, that they need to systematically build up concepts of natural sciences. But there is no strict alternative, no either/or. Students have to get to know the basics of natural sciences as a cultural domain of mankind and to have the chance to achieve this goal on the way of exemplary, genetic, and Socratic teaching and learning.

Cross-References

▶ Curriculum and Values
▶ Didaktik
▶ Scientific Literacy

References

Fischler H (2011) Didaktik – an appropriate framework for the professional work of science teachers? In: Corrigan D, Dillon J, Gunstone R (eds) The professional knowledge base of science teaching. Springer, Dordrecht, pp 31–50

Kant I (1803/1983) Über Pädagogik [About pedagogy]. In: Weischedel W (ed) Kant. Werke in zehn Bänden, vol 10. Wissenschaftliche Buchgesellschaft, Darmstadt, pp 691–761

Klafki W (1998) Characteristics of critical-constructive Didaktik. In: Gundem BB, Hopmann S (eds) Didaktik and, or curriculum. An international dialogue. Lang, New York/Bern, pp 307–330

Klafki W (2000) The Significance of Classical Theories of Bildung for a Contemporary Concept of Allgemeinbildung. In: Westbury I, Hopmann S, Riquarts K (eds) Teaching as a Reflective Practice. The German Didaktik Tradition. Erlbaum, Mahwah, pp 85–107

Nordenbo SE (2002) *Bildung* and the thinking of *Bildung*. J Philos Educ 36:341–352

Wagenschein M (2000) Teaching to Understand: On the Concept of the Exemplary in Teaching. In: Westbury I, Hopmann S, Riquarts K (eds) Teaching as a Reflective Practice. The German Didaktik Tradition. Erlbaum, Mahwah, pp 161–175

Westbury I (2000) Teaching as a Reflective Practice: What might Didaktik Teach Curriculum? In: Westbury I, Hopmann S, Riquarts K (eds) Teaching as a Reflective Practice. The German Didaktik Tradition. Erlbaum, Mahwah, pp 15–39

Biology

▶ Biology Teacher Education
▶ Biology, Philosophy of

Biology Teacher Education

Benny Yung
Faculty of Education, The University of Hong Kong, Hong Kong, China

Keywords

Biology; Teacher professional development

What Is Unique to Teaching of Biology? What Are the Problems and Challenges?

The education of biology teachers, like those for their counterparts in other science disciplines, typically pays attention to common and key issues such as teaching of scientific inquiry, nature of science, and dealing with students' alternative ideas, etc. – the ultimate goal being to develop in teachers the pedagogical content knowledge necessary for effective teaching of science in general and biology in particular.

First, biology is the study of life and its evolution. Indeed, evolution is increasingly used as one of the unifying concepts in developing school science education standards around the world. However, for different reasons, not all biology teachers embrace the notion of teaching evolution in schools (Bybee 2004).

Second, many advances in biology are based upon experimental results and accurate observations in the field. In other words, fieldwork is a key component in understanding biology. However, there has been a decline in fieldwork in schools. One major reason is the insufficient preparation of biology teachers for teaching in the outdoors, teaching in nature (Barker et al. 2002).

Third, biology teachers need to be able to help their students discuss bioethics and the societal implications of biology. They are also expected to help students undertake a range of activities which can help them to develop criticality and to enhance their potential for action. This new vision of biology education for action as well as for knowledge and understanding presents additional challenges for biology teacher education (Zeidler 2003).

How Can Teachers Be Prepared for the Challenges?

Addressing issues of teacher preparation to teach evolution should begin with an assessment of their attitudes, perceptions, and confidence for teaching evolution. Results from surveys suggest that the importance and relevance of evolution to the school science curriculum may need to be explicitly addressed in the education of biology teachers. However, given the politics of teaching evolution in schools (in some countries) and the complexity of the issues involved, a quick solution to this problem is rather unlikely.

To develop critical thinking about societal issues and to enhance the potential for action, students need to be able to analyze scientific information critically as well as to apply it to real world issues. To prepare teachers who can guide instruction of this type, reform of preservice teacher education has been a constant over the past two decades. Promising results were reported by some programs. In these programs, preservice teachers were engaged in identifying research questions where their knowledge of biology could be applied to solving real-life problems. Besides learning how to make informed decisions about science and technology issues in real-life contexts, the preservice teachers were also asked to look into their pedagogical practices to determine the techniques that could be employed to help learners (students) appropriately apply biological knowledge. Hence, through the experience of their own science investigations based on real-life issues, the preservice teachers are given opportunities to learn the various ideas about the pedagogy of science teaching and learning.

Preservice teachers rarely get to prepare and practice teaching in the outdoors in their methods courses or during their practicum. To address this problem, examples of engaging student teachers to actively conduct field trips and having part of their teaching practicum attached to outdoor environments (such as an aquarium or eco-garden) are beginning to emerge. Results show that actual teaching in an outdoor environment empowers teachers and provides them with positive experiences that impact implementation of future outdoor teaching. Results also indicate that teachers should play different roles, rather than traditional ones, in order to function effectively in out-of-school settings. Furthermore, these studies illustrate the potential of reimagining and re-/forming preservice programs to incorporate practicum experiences that go beyond classroom settings. This helps preservice teachers expand their views of biology teaching and learning beyond the boundaries of the classroom-based environment and provides firsthand experience to equip them to move beyond textbook-based biology teaching.

To conclude, while there are commonalities between education for biology teachers and their counterparts in other science disciplines, there are also unique features (as outlined above); some of which require ongoing attention in order to lead to the improvement sought by biology teacher educators more generally.

Cross-References

- ▶ Chemistry Teacher Education
- ▶ Curriculum in Teacher Education
- ▶ Environmental Teacher Education
- ▶ Excursions
- ▶ Pedagogical Content Knowledge in Teacher Education
- ▶ Pedagogy of Teacher Education
- ▶ Physics Teacher Education
- ▶ Science and Society in Teacher Education
- ▶ Secondary Science Teacher Education
- ▶ Teaching Science Out-of-Field

References

Barker S, Slingsby D, Tilling S (2002) Teaching biology outside the classroom: is it heading for extinction? A report on biology fieldwork in the 14–19 curriculum. Field Studies Council Occasional Publication 72. Field Studies Council/British Ecological Society, Preston, Montford

Bybee RW (2004) Evolution in perspective: the science teacher's compendium. National Science Teacher Association Press, Arlington

Zeidler DL (2003) The role of moral reasoning and discourse on socioscientific issues in science education. Kluwer, Dordrecht

---

Biology, Philosophy of

Michael Ruse
Department of Philosophy, Florida State
University, College of Arts & Sciences,
Tallahassee, FL, USA

Keywords

Biology

William James distinguishes between tender-minded philosophers and tough-minded philosophers. No one would use tender-minded as a term referring to Aristotle, the first and the best of philosophers to look at biology, but it does seem true that in the millennia succeeding (especially since the scientific revolution) biology has attracted thinkers who do want to find meaning and comfort in the material world and its explanations. Vitalism, holism, and emergentism were the terms commonly favored.

Things started to change significantly about 50 years ago, when a small group of analytically trained philosophers, including David Hull and Michael Ruse, turned their attentions to the biological sciences, determined to bring understanding and rigor to meta-analyses of the life sciences (Ruse 1988). Today, philosophy of biology is one of the strongest and most popular areas of Anglophone philosophy, with related interest in other academic cultures.

For fairly obvious reasons, evolutionary theory has attracted most attention. It is a topic that raises many issues, for instance, theory structure, the nature of laws, the problems of causation, making claims about past events, many of which were unique, and much more. However, in recent years more and more attention has been paid to related and other areas of the life sciences, including molecular biology, ecology, systematics, and human biology, with special reference to culture and the ways it changes and its interactions with the underlying biological base (Ruse 2008).

Almost all philosophers who have looked at the evolutionary theory have been deeply committed evolutionists. However, in recent years a small group of vocal Christian philosophers, notably Calvinist Alvin Plantinga (2011), have been arguing that so-called intelligent design theory – supposing occasional, nonnatural, important changes – has much to commend it. There is also in such circles considerable doubt about the major claims of paleoanthropology, namely, that humans evolved from apelike creatures, in Africa, breaking free about five or six million years ago, and never were a population less than at least 10,000 members. The critics worry that this kind of thinking is incompatible with the creation story of Adam and Eve in the book of Genesis, and with the subsequent Fall, something thought undeniable for the Christian faith.

Philosophers accepting evolutionary theory have their own controversies, generally focusing on the adequacy or otherwise of the Darwinian account of change, an account that privileges natural selection (the survival of the fittest) as the major cause of change. No one denies that natural selection – the differential reproduction of organism, with consequent success for some with useful variations and failure for others without such variations – has a role to play in the evolutionary process. Intended to speak directly not just to change but to change of a particular kind, namely, adaptive or design-like change, the existence of organic features that used to be known as “final-cause” features, because they serve organisms’ needs or ends – features like hands and eyes, bark and leaves, and hunting ability and defense mechanisms – cries out for a selection-fueled origin.

But how universal is adaptation? Are all or virtually all features of animals and plants adaptive, or is adaptation the exception rather than the rule? Take, for instance, something like the facial hair of human males. Does this have an adaptive role to play, for instance, in keeping men warm (in which case, why do women not have beards) or in sexual attractiveness (in which case why are some human races relatively facially hairless), or is the case rather that facial hair is a by-product of other things, namely, hormones required for the production of male genitalia and so forth, and so in itself has no adaptive function at all.

The philosophically inclined biologists Richard Lewontin (a geneticist) and Stephen Jay Gould (a paleontologist) made much of the supposed nonadaptive nature of many organic features, referring to them as “spandrels,” meaning that they are simply part of the architecture of organisms and selection played no role in their production (Gould and Lewontin 1979). Gould particularly was prepared to state that the Darwinian obsession with what he called “pan-adaptationism” was a relic of earlier natural theological beliefs about God's omnipotence in designing the universe and its contents and as such should have no place in modern secular science.

A related debate has revived the relevance of James's tender-minded/tough-minded dichotomy, for there is much concern about the way in which natural selection operates when it is clearly active. Obviously much that selection does is directed to the benefit of the individual. My eyes are for me to see, not for you to see. But not everything works quite this way. The mammary glands of mammals – breasts, teats, and so forth – are for the benefit of the offspring, not the mother (ignoring possible dual roles like sexual attraction). In a case like this however, since selection operates to promote reproduction, inasmuch as the offspring thrive, the mother's ends are met. But what about nonrelatives? Can selection in one organism promote features that will be of benefit to other organisms? There has been much heated philosophical debate on this subject, with some claiming that selection always acts primarily for the individual and others that it can frequently promote the good of the group, even at cost to the individual. It is clear that much that motivates supporters of "group selection" is a strong dislike of the selfishness of "individual selection," where organisms are seen in a constant struggle of one against all. Nature, such tender-minded thinkers claim, has a gentler, softer side to it. Nature, as the tough-minded thinkers respond, cares nothing for niceness. Thomas Hobbes was right – life is "solitary, poor, nasty, brutish, and short."

Is the philosophy of biology relevant to – or particularly relevant to – science education? Many think that it is and few would want to deny this entirely. On the one hand, a strong case can be made for saying that as soon as the science teacher goes beyond the collecting or observing of particular objects and facts and starts to move towards understanding, philosophy necessarily enters in. One is going to start talking in terms of generalities, laws, and means of explanation, models and hypotheses and theories, and all of this is by its very nature philosophical. In teaching biology, the philosophy of biology has an obvious and essential role.

The following are three examples. First, the student having taken a course in physics where final-cause language is barred – no one asks the function of a volcano or of the moon – wonders why such language is not just allowed but happily and positively permitted in biology, you talk about the function (or nonfunction) of the leaves on a tree or of the appendix in humans. At once one is plunged into metaphors about design and whether a mechanism like natural selection can speak to them. Second, the student having taken a course in chemistry, where substances tend to be substances and no argument, comes to biology and finds that species have all sorts of boundary problems and higher orders like genera are very subjective and fluid. Are modern humans and Neanderthals one species or two, and why? At once one is plunged into all kinds of debates about classification and natural and artificial systems. Third, the student having taken a course in genetics where DNA rules now looks at ecology and wonders what on earth the molecules have to do with the nature of things. What do molecules have to do with the fish in a lake? At once one is plunged into discussions about the relationships between different levels of understanding and whether claims at one level can be explained by, "reduced to," claims at other levels and whether this should always be the aim of science.

On the other hand, in America particularly, but increasingly in other countries, there are those who would constrain or oppose biological understanding for religious reasons. Increasingly this is happening across the board, from evolutionary theory to biomedical technology. Focusing just on evolution, philosophy can and has played a major role in defending the integrity of science. In the past few decades, there have been a number of court cases in America where religiously minded politicians and others have tried to introduce biblically inspired accounts of organic history into state-supported science classes – in Arkansas in 1981, in Louisiana later in that decade, and in Pennsylvania in 2005. In all of these cases, philosophers played an important role in articulating the nature of good science and then showing that modern evolutionary biology, for all its controversies, qualifies as good science, whereas biblically inspired accounts – be they so-called creation science or intelligent design theory – not only are not good science but fail to qualify as science at all. At best they are religious wolves in scientific sheep's clothing, trying to get around the First Amendment separation of the church and the state (Pennock and Ruse 2008).

Philosophy of science is in major respects molded and shaped by the science itself, and as the science changes and develops, so the philosophy likewise changes and develops. The past 50 years have been exciting times for biology, molecular and organismic. The same has been true of philosophy of biology. One expects biology to keep up the same exciting pace of change and development. The same will no doubt be true of the philosophy of biology, and, if anything, its relevance to science education can only grow and deepen.

Cross-References

- ▶ Chemistry, Philosophy of
- ▶ Context of Discovery and Context of Justification
- ▶ Epistemic Goals
- ▶ Mechanisms
- ▶ Models
- ▶ Representations in Science
- ▶ Science Studies
- ▶ Scientific Visualizations
- ▶ Social Epistemology of Science

References

Gould SJ, Lewontin RC (1979) The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme. Proc R Soc of Lond Ser B Biol Sci 205:581–598

Pennock R, Ruse M (eds) (2008) But is it science? The philosophical question in the creation/evolution controversy, 2nd edn. Prometheus, Buffalo

Plantinga A (2011) Where the conflict lies: science, religion, and naturalism. Oxford University Press, New York

Ruse M (1988) Philosophy of biology today. SUNY Press, Albany

Ruse M (ed) (2008) The Oxford handbook of the philosophy of biology. Oxford University Press, Oxford

---

Black or African Ancestry

Mary M. Atwater[1] and Melody L. Russell[2]
[1]College of Education, Department of Mathematics and Science Education, University of Georgia, Athens, GA, USA
[2]College of Education, Department of Curriculum and Teaching, Auburn University, Auburn, AL, USA

An examination of Black ancestry provides insight into both US history and world history. From a historical perspective, Black Americans are the only racial/ethnic group that came to the United States of America initially as involuntary immigrants. Much of their African ancestral language and cultural traditions were destroyed after two centuries of enslavement and bondage. Africans represent a myriad of ethnic groups with over 800 languages. From a more modern perspective, primarily the miscegenation between Africans and Europeans and Africans and Native Americans resulted in the ethnic group more currently identified in the United States of America as "Black Americans" or "American Americans." Furthermore, Black Americans in the United States of America, though descendants of Africa, do not identify with the culture, language, and traditions of their African ancestry since much of their history has been defined on US soil through a lens of westernized culture.

Black ancestry can be characterized through a plethora of historical turning points in US history (i.e., slavery, Civil War, Emancipation Proclamation, Jim Crow, etc.) as the United States of America transitioned from slavery states to free states. It is well known that the largest number of slaves in the Western Hemisphere was in the United States of America, and the gradual transformation from the African identity to the African American identity society that is most familiar with today reveals juxtaposition that has been the source of much internal struggle or conflict.

African Ancestry

The African Diaspora characterizes African ancestry that emerged out of both the voluntary and involuntary migration of Africans throughout the world. The slave trade made the African presence global starting with their capture and enslavement that existed among ethnic groups in Africa, ancient Greeks, and Romans. At least 1,500 years before the Europeans participated in the trade of African slaves, the Arabs (the first mass enslavers of Africans) conducted slave trades of Africans throughout the Sahara Desert, Mediterranean Sea, Indian Ocean, and Red Sea transporting Africans to India, Arabia, and the Far East (Harris 1996). Even with the cruel and inhumane treatment of Africans, many arrived abroad and preserved their languages and traditions calling themselves Africans and Ethiopians. Hence, the African Diaspora refers to what is considered a triadic relationship between Africans as a dispersed group of people back to their homeland and their adopted or host countries (Harris 1996). Even though Africans were enslaved in many places around the world, many valued family and community, preserved cultural traditions, and learned European languages and advanced technology.

Race

Race is socially constructed and has no biological basis as a racial identification and classification. Simply put, there is no Black, White, or Asian gene; technically, there are more genetic differences within a supposedly racial group than across or between groups in order to protect genetic diversity within a group of people. The term "Black" or the notion of "Blackness" emerged as a racial category in Europe and was embraced in the United States of America after the forced relocation of West Africans to the Western Hemisphere. Consequently, the history of Blacks in the United States of America has been largely defined through the lens of Western racism and oppression and has caused a legacy of social, psychological, and economical damage. Specifically, Black Americans in the United States of America have been marginalized and considered a largely "homogenous" group of people, although there is a tremendous amount of diversity within the ethnic group. Even though US history identifies Blackness with a mark of inferiority, the most recent evidence on the origin of *Homo sapiens* points to a single genetic lineage that can be traced back to Africa within the past 200,000 years.

Science

The word "science" in this entry refers to the natural sciences, i.e., biology, chemistry, physics, and geology. The term "science education" refers to the discipline that deals with issues of learning, teaching, curricula, and assessment/evaluation of science in K-14 settings. Due to sociocultural-historical events, people of African ancestry either have not been allowed or few now pursue postsecondary degrees in the natural sciences or science education.

Even though enrollment of international students continues to be critical to the success and diversity of US graduate programs, the relative dearth of students of color in graduate programs is particularly troubling in light of the changing US demographics. Demographers predict that the largest increases in growth among US citizens will continue to be Latinos, African Americans, and Asian Americans. People of African ancestry are 12 % of the US population and 11 % of all students beyond high school; the following percentage of Black high school graduates completed the following science courses: 93.6 % biology, 63.6 % chemistry, 25.8 % physics, 62 % biology and chemistry, and 21 % biology, chemistry, and physics (Aud et al. 2010). Yet in 2009, they received only 7 % of all STEM bachelor's degrees, 4 % of master's degrees, and 2 % of Ph.Ds. (National Science Board 2012). In 2008, 824 Blacks out of 48,802 received doctorates in science and engineering (National Science Foundation 2009), while in 2009, only 88 Black males (1.3 %) out of 6,957 received Ph.Ds. in the biological and biomedical sciences.

Historical and Social Factors

These low numbers are the result of complex historical-sociocultural factors from self-doubts, stereotypes, discrimination, oppression, and economics. Arliner Roger Young, a zoologist, was the first African American woman to receive a Ph.D. from the University of Pennsylvania in 1935 professionally published in the field. She had to deal with gender, race, and educational barriers of her time which were no small matters. Unfortunately, she died on November 9, 1964 in New Orleans, poor and alone (Hodges n.d.). In 1943, Lloyd Noel Ferguson was the first African American male to receive a Ph.D. from the University of California, Berkeley, in chemistry and authored more than 50 journal articles and seven textbooks on cancer chemotherapy, the relationship between structure and biological activity, and the chemistry of organic compounds and properties such as odor and taste (Morris 1992).

With segregation legal in the United States of America for many years, it was difficult for Blacks to pursue degrees in the sciences and even more difficult for them to gain employment. Those who obtained science Ph.D. in the early years usually gained positions at Howard University. When segregation was no longer legal in the United States of America, many traditionally White institutions (TWIs) fought against desegregating its student body. Even today, many Blacks cannot pursue science degrees because they do not meet the entry requirements of TWIs. However, progress is being made by those Black students who receive quality precollege education that allows them to meet entry requirements to pursue science degrees even though the cost of postsecondary science education remains to be prohibitive for many.

Present Major Challenges at the Precollege Level

Based on international, national, and state science achievement scores, the quality of K-12 science student learning varies. In the United States of America, suburban, middle class K-12 Asian and European American students perform better on standardized test than other student groups. These test scores usually are used as indicators of the quality of student science learning. Even though differentiated teaching is encouraged, the practices of “grouping by ability” and tracking continue to occur in US schools. These practices give students different access to school resources such as certified teachers with advanced science degrees, updated science textbooks and other curricular materials, and modern science laboratory equipment and materials and opportunities to participate in other science enrichment programs such as summer science programs, after-school science programs, and field trips to museums and zoos.

Science is a way of knowing; the key to understanding science is to grasp the language of science and education The native language of students influences their opportunities for quality science learning because it (a) structures both students’ and teachers’ science learning and (b) determines how they use the language to understand and communicate their understanding of natural phenomena. If the language of science is truly understood, it helps the learner to engage in deductive and inductive reasoning, make hypotheses, generalize research findings, connect evidence to theses, and persuade others. Home language, instructional language, and science language problematize science learning because students must move across communities of family, school, and science. This is especially true when students’ home language is not the same as their instructional and science languages. Since language is a part of students’ culture, it has been suggested that students’ limited adeptness in English restricts their science learning and performance when instruction, assessment, and evaluation are done exclusively or predominantly in “standard English.” Hence, students who are Black English language learners (ELLs) such as Haitians do not perform as well as students whose first language is English. However, when the Black language dialect of African-Americans is used by physics teachers, these students build new physics understanding (Elmesky 2001).

To encourage learning in some groups, adaptations are made for different groups of students. Unfortunately, large numbers of Black students are found in “special education classes” in which few adaptations such as (a) altering the directions, assignments, and testing procedures and (b) including more activity-oriented lessons occur. According to Moje et al. (2001), compatibility among literacy, science learning, and language in diverse classrooms requires four interrelated classroom interactions. Science teachers need to (a) draw from students’ everyday languages and understandings, (b) develop students’ awareness of those various languages and knowledge bases, (c) connect student everyday understandings and languages with the science language of science classrooms and of the science community, and (d) help students to negotiate understanding of both languages and understandings so that these understandings not only inform each other but also merge to construct a new kind of language and understandings.

The science teaching force in the United States of America does not reflect the K-12 student population. In 2007, 45 % of the US K-12 students were Blacks, Latinos, Asian/Pacific Islanders, native Americans, and Alaskan natives (Hussar and Bailey 2011), while in 2008, 21 % of students aged 5–17 spoke a language other than English or spoke English with difficulty (Aud et al. 2010). However, only 7.8 % of the elementary and secondary teachers in 2008 were Blacks, native Americans, Alaskan natives, and Asian and Pacific Islanders (School and Staffing Survey 2008). Haberman (1996) maintains that urban teachers are successful if they have experiences similar to their students such as tragedy in the form of the death of a loved one; critical, life threatening injuries to family members; violence at home; serious unforeseen injuries; poor nutrition and sleep habits; or mental and emotional problems.

Present Major Challenges at the College Level

Blacks are about as likely as White freshmen students to declare science and engineering fields as majors, and Blacks who enroll in or graduate from college are about as likely as Whites to choose science and engineering fields (National Science Board 2012). However, Black females are more likely to complete undergraduate degrees than males (Harper 2012) and more likely to obtain bachelor degrees in biology. Once Black students enter a college or university to major in the sciences, they have additional challenges such as high school preparation, financial support, and the lack of mentoring. If they enter a traditionally White university, additional coping skills are needed to deal with the university’s culture. Even if these Black students graduate with a science degree and pursue doctorates, they continue to have challenges such as having the lowest rates of research assistantships and research publications (Council of Graduate Schools 2012).

People of African ancestry will continue to be challenged to experience equitable science learning and teaching and to contribute to scientific fields. But as in the past, Blacks in the future will continue to enhance the world’s understanding of natural phenomena and to utilize those understandings to better the lives of all human beings in novel ways. Blacks have made tremendous contributions to science, and though presently there are more of them in the biological and physical sciences, their representation in degree programs and careers is still sparse compared to other US groups. In order to increase their numbers, more must be done to overcome the legacy of racial and social inequities that still persist today in the United States of America and the world.

Cross-References

- ▶ Asian Ancestry
- ▶ Cultural Influences on Science Education
- ▶ Cultural Values and Science Education
- ▶ Latino Ancestry
- ▶ Pacific Island Ancestry

References

Aud S, Fox MA, KewalRamani A (2010) Status and trends in the education of racial and ethnic groups. National Center for Education Statistics, U.S. Department of Education, Washington, DC, Retrieved from http://nces.ed.gov/pubs2010/2010015.pdf

Council of Graduate Schools (2012) Overview of research on underrepresented populations in graduate school. Retrieved from http://www.cgsnet.org/cgs-occasional-paper-series/memphis-university/part-1

Elmesky R (2001) Struggles of agency and structure as cultural worlds collide as urban African American youth learn physics. Unpublished doctoral dissertation, Florida State University, Tallahassee

Haberman M (1996) Selecting and preparing culturally competent teachers for urban schools. In: Sikula J, Buttery TJ, Guyton E (eds) Handbook of research on teacher education. Simon & Shuster Macmillan, New York, pp 747–760

Harper S (2012) Black male students success in higher education: A report from the Black male college achievement study. University of Pennsylvania Center for the Study of Race and Equity in Education, Philadelphia, Retrieved from https://www.gse.upenn.edu/equity/sites/gse.upenn.edu.equity/files/publications/bmss.pdf

Harris JE (1996) The dynamics of the global African diaspora. In: Harris JE, Jalloh A, Inikori JE, Palmer CA, Graden DT (eds) The African diaspora. Texas A&M University Press, College Station, pp 7–21

Hodges F (n.d.) Roger Arliner Young. Retrieved from http://www.answers.com/topic/roger-arliner-young

Moje E, Collazo T, Carillo R, Marx RW (2001) Maestro, what is 'Quality'? Language, literacy, and discourse in project-based science. J Res Sci Teach 38(4):469–498

Morris G (1992) Increasing opportunities for in chemistry, 1936–1986 Lloyd Noel Ferguson. Regional Oral History Office, the Bancroft Library, University of California, Berkeley, Retrieved from http://content.cdlib.org/ark:/13030/kt809nb2nd/

National Science Board (2012) Science and engineering indicators 2012. (NSB 12-01). National Science Foundation, Arlington, Retrieved from http://www.nsf.gov/statistics/seind12/c2/c2s2.htm#s2

Blogs

▶ Blogs for Learning
▶ Web 2.0 Resources for Science Education

Blogs for Learning

Kihyun Ryoo[1] and Elissa Sato[2]
[1]University of North Carolina, Chapel Hill, NC, USA
[2]University of California, Berkeley, CA, USA

Keywords

Biology

Blogs for Learning

A blog is an online space where individuals can publish any form of written work, such as reflections, as a sequence of entries that are often presented in reverse chronological order. In most cases, anyone with Internet access and access permissions can read blog entries and leave comments, which allows interactive communication between writers and readers. Blogs are used widely across the Internet as a means of informal publication and commentary and have also been applied within education communities as a teaching and learning tool to help students develop a range of skills. For instance, blogs can provide rich opportunities to improve students' writing skills. Blogs can create collaborative learning environments that enable students to share various ideas and perspectives, not only with their classmates, but also with a broader audience. Blogs also allow teachers or peers to assess student progress at various stages of instruction and provide timely feedback. Recently, researchers have begun to explore the benefits of such ongoing and iterative written reflections for students' learning. For example, Alexander Renkle and his colleagues (Glogger et al. 2012) have developed a program of research to study the effects of journal writing as a follow-up activity of classroom instruction in helping students reflect on what they have learned in the classroom and identify areas for improvement.

Blogs have the potential to create unique learning opportunities that encourage students to write longer accounts of scientific phenomena than typical short response items and facilitate iterative refinement — important yet often ignored elements of science instruction. For instance, blogs can be implemented in science instruction as a journal that allows students to continuously add their own ideas or other evidence they have discovered about scientific phenomena across topics and grade levels. As students progress through instruction, they can generate, reflect on, and organize their growing repertoire of ideas. Students can also monitor their own progress by reviewing the history of their writing entries and iteratively refine their ideas. Such opportunities could help students develop a more sophisticated understanding of complex science concepts and make connections among various science topics.

To take advantage of blogs for science learning, teachers need to carefully create activities and prompts that engage students and facilitate reflective, iterative writing processes. One instructional strategy is to embed blogs within inquiry activities. Inquiry-based instruction challenges students to develop a deep understanding of scientific concepts through scientific practices, such as making predictions, designing experiments, collecting evidence, analyzing data, and articulating their ideas. This approach requires students to constantly reflect on their learning progress and integrate multiple ideas and perspectives to develop a coherent understanding. Blogs could be used to support students through this process by keeping track of their evolving understanding in the form of written artifacts.

One example of reflective writing in a technology-enhanced inquiry approach is found in the student-generated explanatory narratives, called Energy Stories, employed by the Web-based Inquiry Science Environment (WISE – see Slotta and Linn 2009). Energy Stories prompt students to write a coherent story about energy concepts within a system by making connections among various energy ideas, such as energy sources, energy transformation, and energy transfer. For instance, seventh-grade students wrote Energy Stories about how a rabbit gets and uses energy from the sun across two WISE units in life science (Ryoo and Linn 2012). Students were asked to incorporate all the information from instruction, as well as evidence collected from visualizations, to write coherent narrative accounts of where energy comes from, how energy is transformed, and where energy goes. Students wrote three Energy Stories as they progressed through the units and revised their stories based on feedback from teachers. Energy Stories captured the details of students' understanding about the role of energy in the ecosystem and revealed how they built on their prior knowledge. Many students started with non-normative ideas about energy but became able to synthesize normative energy ideas, such as how light energy is transformed and how chemical energy is transferred, and use those ideas to restructure their initial understanding of energy flow in life science (see Table 1 for one example of a progression of student Energy Stories).

Energy Stories provided students with opportunities to reflect on the ideas they had investigated in two WISE units and to articulate them in their own words, which increased the coherence of their scientific explanations and deepened their understanding of how energy flows in life science. Energy Stories also helped teachers better understand how students were developing an integrated understanding of complex scientific concepts and linking energy ideas across the two units. One of the seventh-grade science teachers was amazed by the value of Energy Stories as both a learning activity and an assessment tool, saying, "It's a summary of what has happened, and they're writing it in their own words. . . it just encapsulates everything that had happened."

These findings underscore the value of blogs in providing recurring opportunities for students to iteratively integrate, reconsider, and refine their ideas about complex scientific phenomena. For teachers, this type of reflective writing provides opportunities to assess students' progress and provide timely feedback, which can strengthen instruction. Blogs can thus be an effective means of enacting such practices in the classroom.

Blogs for Learning, Table 1 Sample Energy Stories from a seventh-grade student across two WISE units

Initial Energy Story	The energy comes from the sun which goes into the chloroplast of the plant cells. There the energy gets transformed into plant food
Revised Energy Story	Once upon a time there was a plant. The plant had a job of making food for his rabbit. To make energy-rich food for the rabbit, the plant's chloroplasts collected water, light energy and CO2 for the food which is called glucose. Glucose is a type of sugar used to help plants stay alive and grow. In the plant's chloroplast, the light energy breaks apart the little water and CO2 atoms. When the light energy broke apart the atoms, it turned into chemical energy which decided to go inside the glucose and help give nutrients to the rabbit and the plant. The glucose traveled around the body and the extra ones were stored in the roots and leaves. When the rabbit ate the plant, the plant gave away some of the glucose. Even though it was very complicated to make glucose, the plant was happy to be generous
Final Energy Story	Once upon a time, there was a plant. The plant fed a rabbit named bobby. Bobby ate the plant's nutritious leaves full of glucose. The plant woke up every morning just before dawn. To make glucose, the plant needs sunlight, water, and CO2. The plant collected sunlight and CO2 with his leaves. His roots soaked up the water. All the CO2, water, and sunlight gathered up at the chloroplast where the water and CO2 atoms were broken apart and the sunlight was changed into chemical energy. The atoms were assembled into glucose molecules and the chemical energy was stored in the glucose. The left over atoms were made into oxygen. The glucose was stored in the leaves and roots for later use. Then Bobby came along and ate a leaf from the plant. The leaf went into Bobby's stomach and his stomach cells extracted the glucose from the leaf. The glucose went into the mitochondria with oxygen and the glucose and oxygen were broken apart into smaller pieces (atoms). The chemical energy was taken away from the glucose and the atoms of the glucose and oxygen molecules assemble themselves into CO2 and water molecules

Cross-References

- ▶ Computers as Learning Partners: Knowledge Integration
- ▶ Digital Resources for Science Education
- ▶ Online Inquiry Environments
- ▶ Technology for Science Education: Research
- ▶ Wikis

References

Glogger I, Schwonke R, Holzäpfel L, Nückles M, Renkl A (2012) Learning strategies assessed by journal writing: prediction of learning outcomes by quantity, quality, and combinations of learning strategies. J Educ Psychol 104(2):452–468

Ryoo K, Linn MC (2012) Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis? J Res Sci Teach 49(2):218–243

Slotta JD, Linn MC (2009) WISE science: web-based inquiry in the classroom. Teachers College Press, New York

---

Borders/Border Crossing

Maria Andrée
Department of Mathematics and Science Education, Stockholm University, Stockholm, Sweden

Border crossing provides a lens for analyzing science learning as cultural acquisition and science teaching as cultural transmission. Thus, science is deemed as culture rather than absolute truth. The generic construction of border crossing assumes the existence of borders between two (or more) distinguishable cultures/subcultures that, to a varying degree, represent obstacles for individuals to cross. The notion of border crossing has been used widely in science education research to conceptualize difficulties that students encounter in science education. In research, science classroom experiences of students and teachers have been theorized in terms of the ease with which students and teachers cross cultural borders of the science classroom. Border crossings have been categorized as *smooth*, *manageable*, *hazardous*, or *virtually impossible* (Cobern & Aikenhead, 1998). The concept of border crossing was borrowed from cultural anthropology and first applied to Western students studying science by Aikenhead (1996) with an expressed aim to encourage science educators to acknowledge inherent border crossings between students' lifeworld subcultures and the subculture of science. The theoretical framework of cultural borders and border crossing have later been challenged for assuming subcultures as given entities and not fully taking hybridity, heterogeneity, and the situatedness of cultural practices into account (Carter, 2008).

Cross-Reference

▶ Acculturation
▶ Culture and Science Learning

References

Aikenhead G (1996) Science education: border crossing into the subculture of science. Stud Sci Educ 27:1–52

Carter L (2008) The armchair at the borders: the "messy" ideas of borders and border epistemologies within multicultural science education scholarship. Sci Educ 94:428–447

Cobern WW, Aikenhead GS (1998) Cultural aspects of learning science. In: Fraser BJ, Tobin KG (eds) International handbook of science education. Kluwer Academic Publishers, Dordrecht, pp 39–52

Botanic Gardens

Ellen McCallie
National Science Foundation, Arlington,
VA, USA

Botanical gardens are collections of well-documented and maintained living plants. While best known for aesthetic displays and tranquil settings, botanical gardens are key scientific research and conservation institutions as well as rich environments for learning.

The Purposes and Value of Botanical Gardens

The International Association of Botanic Gardens estimates that there are just under 1,800 botanical gardens in approximately 150 countries worldwide. Collectively, they serve approximately 150 million visitors a year. Botanical gardens generally aim to promote (1) scientific research, (2) conservation, (3) education, and (4) leisure experiences.

Learning in Botanical Gardens

Learning is a diverse endeavor. It encompasses a wide range of experiences, such as content acquisition, excitement and motivation, skill development, reflecting on the process of science, contributing to the generation of scientific knowledge, and identifying oneself as a scientist or science learner.

As places for learning, botanical gardens are designed to evoke emotion and reflection, prompt questions and exploration, and provide guidance and information. They actively seek to repair people's relationship with nature (sometimes referred to as "nature deficit disorder" (Louv (2005)), as well as people's lack of recognition that plants form part of the foundation of human culture and society by providing food, medicine, fiber, and building materials (referred to as "plant blindness" (Wandersee and Schussler 1999)). Learning experiences across botanical gardens vary, because they leverage the specific mission and resources of each botanical garden in order to meet the needs of their communities.

Botanical gardens' most prominent educational (and leisure) resources are their outdoor gardens and greenhouses (glasshouses) that focus on plant and garden displays. Common plant and garden displays include native plants; specialty plant groups like cacti; cultural gardens;

home gardens with flowers, edible plants, and sustainable living components; immersive environments that seek to replicate specific ecosystems like cloud forests; children's gardens; and scientific gardens that highlight biodiversity and evolutionary relationships among plants. In addition, botanical gardens often incorporate art and historic buildings as part of their displays.

Most botanical gardens offer educational programming. Four examples illustrate the range and diversity of learning opportunities offered. First, some botanical gardens train volunteer master gardeners and "plant doctors," who provide identification services and advice to visitors, in-person, online, or on the phone.

Other institutions have community gardens tended by local residents. In some programs, recent immigrants or rural transplants grow plants that represent their culture or life experiences. Using their harvests, participants share culinary and cultural practices. This facilitates community understanding as well as intergenerational dialogue within families. Such programs may also be combined with literacy opportunities for participants.

Common across botanical gardens are professional development offerings for K-12 teachers. Since the early 1990s, these classes have focused on teaching inquiry-based pedagogy and lending hands-on kits for classroom and community use. The classes and kits align closely with local, state, and national curricula in science, technology, engineering, and mathematics (STEM), as well as art and literacy standards.

Finally, many botanical gardens host festivals. Whether focused on green living and energy conservation, the sculpture of a country or an artist, seasonal changes, or religious observances, these festivals bring communities together and enrich the lives of visitors and increase their understandings of the natural world and human cultures.

Scientific Research, Conservation, and Learning at Botanical Gardens

Though few outside the botanical community get "behind the scenes," many botanical gardens are major research institutions, focusing on plant biodiversity, evolution, conservation, and sustainability. Documenting, studying, and preserving plant life and ecosystems are consistent with the history and commitment of botanical gardens. Some of the major botanical gardens in the world were founded in order to grow the strange, beautiful, medicinal, or economically important plants collected during times of exploration. Today, scientists at gardens are in a race against time to collect and study plants before they disappear due to urbanization, suburbanization, and agriculture. Approximately 80,000 of the 270,000 known species of plants are in cultivation in botanical gardens, including those that are threatened or endangered.

Scientific research, conservation, and learning at botanical gardens are often integrally connected. Programs at botanical gardens may include lectures or workshops on current scientific research and conservation efforts, tours of research labs or herbaria (collections of dried plant specimens; herbarium, singular) and conservation areas, or volunteer opportunities to work with research and conservation staff. In addition, some botanical gardens offer classes and degree programs at the university level. In addition, learning research also occurs at botanical gardens (see, e.g., Eberbach and Crowley 2009).

Challenges for Learning in Botanical Gardens

There are at least three major challenges for botanical gardens in achieving their educational aims. First, as enthusiasts and professionals alike report, becoming a gardener, a scientist, or someone knowledgeable about plants and the environment entails getting directly involved with one's subject matter. Whether crushing leaves to identify a plant by smell, collecting seeds for spring planting or conservation efforts, or using blossoms to create art, hands-on experiences are critical for learning. These authentic experiences are a resource challenge for botanical gardens. For example, for a garden to provide digging, planting, and harvesting opportunities for visitors, it must make a significant commitment in terms of staff, greenhouse space, and other resources to maintain a continuous supply of plant materials and supervised experiences.

Second, by striving to reach multiple and varied audiences, botanical gardens experience ongoing tensions between achieving a well-tended garden with a tranquil, idyllic atmosphere and creating a garden that is welcoming to people of all ages and interests. This tension plays out in terms of what learning experiences are offered, when, and to whom (Sanders 2007).

Third, time is needed for learning in botanical gardens. It is needed in two ways: time for nature and time for people. For example, time is necessary for plants to grow, for experiments to take place, and for seasons to change. In addition, time is needed for people to experience and enjoy the breadth and intricacies of botanical gardens and their offerings. In order to address both these issues, botanical gardens often promote memberships and events, provide classes in extended series, and encourage repeat visitation throughout the year and over years to foster greater understanding of the natural world and human cultures.

Summary

Botanical gardens are institutions that are deeply committed to and actively engaged in providing visitors with meaningful learning experiences, focused on the themes of biodiversity, evolution, conservation, and sustainability. The displays and programs botanical gardens offer are designed to appeal across age and interest groups and to address the full spectrum of what it means to learn.

Links to Some Significant Botanical Gardens

Kirstenbosch National Botanical Garden, South Africa http://www.sanbi.org/gardens/kirstenbosch/
Missouri Botanical Garden, US http://www.missouribotanicalgarden.org/
The Eden Project, UK www.edenproject.com/
New York Botanical Garden, US www.nybg.org

Cross-References

▶ Aquaria
▶ Excursions
▶ Interpretive Centers
▶ Learning Science in Informal Contexts
▶ Lifelong Learning
▶ Out-of-School Science
▶ Zoological Gardens

References

Eberbach C, Crowley K (2009) From everyday to scientific: how children learn to observe the biologist's world. Rev Educ Res 79(1):39–68
Louv R (2005) Last Child in the woods, Algonquin Books
Sanders D (2007) Making public the private life of plants: the contribution of informal learning environments. Int J Sci Educ 29(10):1209–1228
Wandersee J, Schussler E (1999) Preventing plant blindness. The American Biology Teacher 61(2):82–86

Bridging

▶ Access of Historically Excluded Groups to Tertiary STEM Education

---

Broadcast Media

David Robinson
Faculty of Science, The Open University, Milton Keynes, UK

Broadcasting is primarily about dissemination. One source distributes to many potential recipients, who, if they are aware of the broadcast at all, can choose to engage or ignore. It is essentially a one-way communication process although technological advances are increasingly adding forms of interactivity and audience involvement. The principal broadcasting media are sound and vision, initially distributed in real time using signals transmitted through the air, but now accessible through a wide range of other distribution channels. The advent of recording media, and later on download on demand via the Internet, removed the need to make "an appointment to view," but listening and viewing scheduled transmissions is still the main way in which people access broadcast media.

Broadcast media contribute to science education in a variety of different ways. The BBC in the UK was founded with a commitment to public service broadcasting that aimed to contribute to cultural life. The first director general, John (later Lord) Reith, formulated the purpose of the BBC as to "educate, inform and entertain." The annual broadcast lectures that now bear his name have, since 1948, allowed some of the leading scientists who are also great science communicators to bring science to a wide, and international, radio audience. Although the lectures provide an immediate experience for the listener at the time of transmission, the archived lectures provide a continuing resource for education, both formal and self. These lectures can prove powerful calls to action. For example, the 1969 lectures by the ecologist Frank Fraser Darling are a major milestone, because from a position of great authority, he articulated an early warning of global warming.

Science broadcasting in Germany started in 1923, and by 1925 one regional radio station broadcast a science lecture every Monday at 7:30 p.m. Across the radio stations the quantity of science programming was high, and science was generally broadcast during prime time, not so much because it was popular then among the listeners, but more because it matched the educational and cultural philosophy of the state. Deutsche Welle (1926–1932) was a national educational radio station with science programs that were aimed at a general audience. There were also programs aimed at a learning audience and those wishing vocational training. The regional stations did not reduce their science contact, so science enthusiasts had choice. Additional supporting material was provided for some programs through a magazine, so the idea of the use of multiple media in educational broadcasting is quite an old one (Schirrmacher 2012). The present Deutsche Welle is a German international broadcaster and is unrelated to the earlier radio station.

The lecture is a traditional form of communication that transfers well to radio, but developments in television have produced two strong new strands of science education and involvement. Firstly, there is the involvement of viewers in scientific events, in the past the moon landings and in more recent times the search for the Higgs boson. Here, broadcast media clearly have a role in communicating science by explanation, but there is also the immersion of the audience in the atmosphere and excitement of the event itself. For almost 50 years postwar, this strand of science education represented a unique selling point for terrestrial and satellite broadcasters. Now, the Internet has provided new channels which can provide the experience and often enhance it. CERN, the European Organization for Nuclear Research, has a channel CERN News that provides regular programs about the physics experiments conducted at the laboratories. NASA TV has live coverage of its space research, viewable on computers and mobile devices.

The second strong strand that developed in television, particularly in the UK, was direct broadcasting to specific groups. School radio was established early on, and by 1930 there were already science broadcasts for schools, with programs designed to be included within the planned lessons during the day. Schools broadcasts on science on television followed in the 1950s, again being used within the school timetable. In 1971, the Open University started to broadcast programs directly related to individual undergraduate degree courses. Television and radio became the medium for the distribution of learning to students, and the programs were much more than lectures, encompassing in due course some very innovative science programming. The Open University of Japan broadcasts lectures in a traditional format to its students nationwide. The key point about all these developments is that while they are targeted at particular audiences, the "drop-in" audience can be highly significant. An Open University program between 1971 and 2000 might well have been aimed at a course of 400 students, but the drop-in audience would have been many times that figure, and, on at least one occasion, it reached one million for a single program. It is difficult to measure the educational effectiveness for the drop-in audiences, although there are a number of students who give broadcasting as their reason for applying for courses.

As technology has developed, so has the broadcast model. A science broadcast now may be part of a complete package focused around a "call to action." The call might be for audience participation in a specific activity or a more general call to do something positive, for example, volunteering for conservation projects. The package, supported by web pages, might also include a free print item that can be requested by telephone or online and road shows that provide the opportunity for some hands-on science. A recent innovation has been to associate a Twitter feed with a program and build the audience into a community who take the subject beyond what was actually broadcast. The ready availability of podcasts for download enables people to choose when to listen to a program and effectively increases the size of the audience. There have also been courses for credit linked to TV programs. The BBC's Natural History Unit (Gouyon 2011) produced a blue chip documentary series in 2011 called "Frozen Planet." It was presented by Sir David Attenborough, and the series had a free poster and a short, 10-week course of the same title, dealing with polar science. The packaging of many components around a broadcast, sometimes called 360° programming, has considerable potential for science educators to harness the power and reach of the broadcast media to bring science activities to a wide audience.

BBC Lab UK is a website where the public can take part in scientific experiments linked to broadcast programs. Scientists are invited to submit experiments that could benefit from mass participation. One of the most successful was the 2006 Sex ID experiment that formed part of the TV series "Secrets of the Sexes." Scientific papers based on the data collected were published in a complete edition of the journal *Archives of Sexual Behaviour*. There were 250,000 participants, a figure that demonstrates the power of the broadcast media to promote engagement with science.

Broadcast Media, Table 1 Science broadcasting on terrestrial free-to-view channels in the UK for 1 week (October 2005)

Available broadcast hours on channels with a minimum of 1 program on science in the week (10 in all)	1,022 h
Broadcast hours devoted to science	29 h including repeats
Percentage of available time	2.9 %
Categories included	Science, earth science, nature, forensics, health, scientific archaeology, science history, and science medicine

There is plenty of potential for the broadcasting media to grow their role in science education, but analysis of factual science output suggests that the overall penetration of science into broadcast media is poor (Table 1). A study of the share of science programs on the Flemish Radio and TV network VRT showed that between 1997 and 2002 it varied between 2.97 % and 5.23 % (Maeseele and Desmet, 2009).

The image of scientists as projected by radio, and more particularly television and film, is often negative and in drama sometimes far removed from reality. Male scientists tend to be represented as the norm and female scientists as exceptional. *MythBusters* from the Discovery Channel is a program that explicitly sets out to depict the culture of science and engineering in as accurate a way as possible, with the aim of remedying the lack of understanding of the subject areas among high school students and encouraging more to take them on. The series also tries to show people in the fields of science and engineering as realistically as possible (Zarvel 2011). The representation of science and scientists by the broadcasting media is an area of continuing debate, with the impression among scientists that they and their subject are underrepresented in broadcasting. Such figures as there are seem to bear this out. In 2012 the BBC appointed its first science editor, a welcome move, but editors for other subject areas have existed for many years.

There are tensions between, on the one hand, engaging the attention of the audience and retaining it through a program and, on the other, showing authentic and accurate scientific knowledge. This can be a very fine line, as the *MythBusters* series in the US and the *Bang Goes the Theory* series in the UK demonstrate. In each, audience excitement and scientific accuracy go hand in hand, but it is a difficult relationship to maintain. There are also tensions visible in programs about extinct animals where CGI (computer-generated imagery) techniques bring extinct animals alive on the screen. *Walking with Dinosaurs* was produced as if it was a natural history series, and although it had input from many scientists, particularly concerning biomechanics, it was criticized for including behavior, such as "bonding for life" for which there is no scientific basis (Campbell 2009). When fact and guesswork are mixed, without signposting, the science educator becomes uneasy.

The power of broadcast TV to disseminate science has been covered by a number of authors (e.g., the book by Willems and Göpfert 2006). However, there is an element of broadcast TV that is less well studied, and that is the commercial breaks between programs, which also contain science content. A study carried out in 1999 found that 65 % of all advertisements over a 2-week period marketed science-based products. It has been suggested that advertisements could be used to learn about science and, by examining them in detail, demonstrate the need for objectivity.

So for the future, science educators increasingly will be using the broadcast media as a source of material for learning, as a way of educating the general audience about science and its place in society, and for demolishing the negative stereotypes of scientists.

Cross-References

- ▶ Citizen Science
- ▶ Online Media
- ▶ Radio
- ▶ Television

References

Campbell V (2009) The extinct animal show: the paleoimagery tradition and computer generated imagery in factual television programs. Public Underst Sci 18:199–213

Gouyon J-B (2011) The BBC natural history unit: instituting natural history film-making in Britain. Hist Sci 49(4):425–451

Maeseele P and Desmet, L (2009) Science on television: how? Like that! J Sci Comm 8(4).

Schirrmacher A (2012) State-controlled multimedia education for all? Sci Educ 21:381–401

Willems J, Göpfert W (eds) (2006) Science and the power of TV. VU University Press & Da Vinci Institute, Amsterdam, p 184

Zarvel EA (2011) How the discovery channel television show Mythbusters accurately depicts science and engineering culture. J Sci Educ Technol 202:201–207